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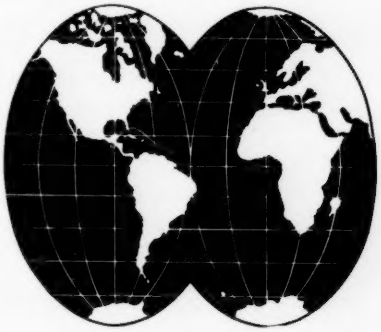

14-15-16 MAY, 1959

Biltmore Hotel

Atlanta, Georgia

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DIRECTOR OF PROCEEDINGS

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Foreword

The National Industrial Engineering Conference, initiated in 1949 by a group of enthusiastic pioneers in industrial engineering from education and industry, has, through the years, grown in size and stature as the nation's only leading forum of industrial engineering. This growth has stimulated interest in research, development and application of industrial engineering. The program this year is indicative of the fact that this growth is continuing.

We are pleased to present herein a complete printing of the speeches and papers presented at the 1959 National Conference of the American Institute of Industrial Engineers. A table of contents is included for your convenience.

Your committee for this conference wishes to express their thanks and appreciation to all those who have presented papers and to all others whose participation has contributed to the success of the conference.

Robert G. Provost, Sr.

Robert G. Provost, Sr.
Director of Proceedings

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J. Frederick Medford
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ATLANTA, GEORGIA

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Industrial Engineering is concerned with
the design,
improvement,
and installation of
integrated systems
of men,
materials
and equipment;
drawing upon
specialized knowledge
and skill
in the mathematical,
physical,
and social sciences
together with
the principles
and methods
of engineering analysis
and design,
to specify,
predict,
and evaluate
the results
to be obtained
from such systems.

THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS
OCTOBER 1955

Purposes of the AIIE

The AIIE *is dedicated to the following purposes:*

To maintain the practice of Industrial Engineering on a professional status

To foster a high degree of integrity among the members of the industrial engineering profession

To encourage and assist education among members of the profession

To promote the interchange of ideas and information among members of the profession

To serve in the public interest by identification of men qualified to practice as Industrial Engineers

To promote professional registration of Industrial Engineers.

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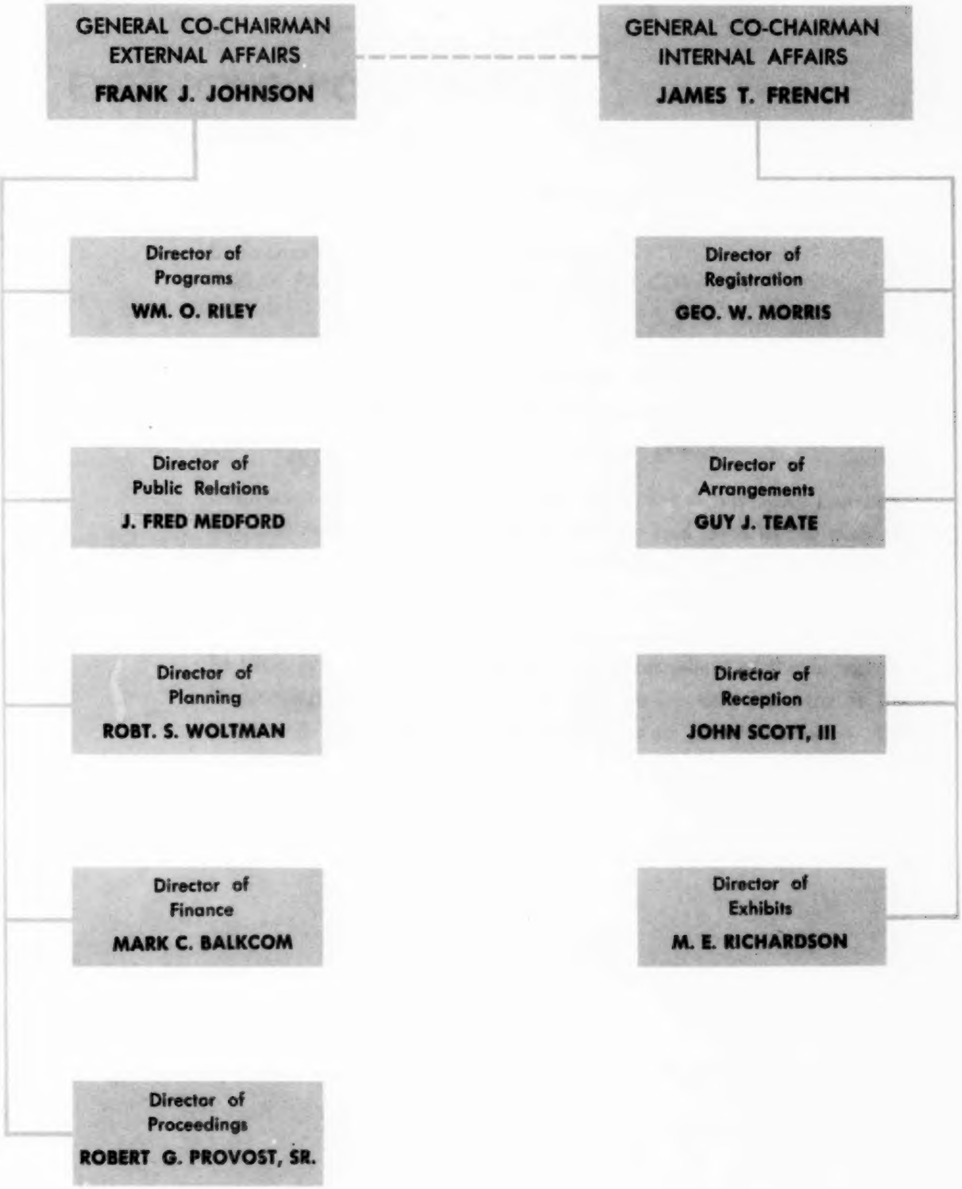

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section 1

EXPANDING HORIZONS

by **GEORGE H. GUSTAT**
President
AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS
and
Director of the Engineering Industrial Division
KODAK PARK WORKS, EASTMAN KODAK COMPANY

Since receiving his B.S. in Economics and Chemical Engineering in 1930 from the University of Illinois, Mr. Gustat has served the Eastman Kodak Company in a variety of positions.

Beginning in 1930 as a trainee assigned to the Advertising, Accounting, and Service Departments, by 1933 he had risen to the position of Assistant Manager in the Export Shipping Office. After working as a Standard Cost Engineer and Supervisor, in 1946 he was made Assistant Superintendent of the Wage Standards Department. In 1949, Mr. Gustat was appointed Superintendent of the Industrial Engineering Department, and in 1954 he became Director of the Industrial Engineering Division at Kodak Park Works — the position he holds today.

EXPANDING HORIZONS

by George H. Gustat
President
American Institute of Industrial Engineers
and
Director of the Industrial Engineering Division Kodak Park Works, Eastman Kodak Company

I WOULD like to add my welcome to all of you to this 10th Annual Conference of the American Institute of Industrial Engineers.

Problems of the World Create the Need for the Engineering Disciplines

If there were no problems in the world, it is a pretty good probability that this conference would not be taking place at all. The fact that someone thought there were problems and that they need solutions has provided us with the subject material and a title for this conference.

The Geometric Nature of Problems Force the Expansion of Our Engineering Horizons

A horizon can be defined as a limit of perception or experience. A problem for which you do not know the solution, is, of course, always beyond that point.

Every time one of these problems is solved our horizon is pushed back or expanded until today we can see quite a distance into the future. However, there is another principle involved in problem solution. Every time one problem is solved several others that we were not even aware of come to light. For example, early man's knowledge of the world was concerned with only three basic elements: earth, water, and air. Life was relatively simple and problems were not staggering in their complexity. As his knowledge grew, man discovered that there were many more basic elements of matter, until today there are 102 in the Periodic Tables. As each new element is discovered, a whole new set of problems come with it concerning its nature and usefulness.

Man's curiosity about these problems has led him farther, and now we know that even these basic elements can be broken down into protons, neutrons, mesons, etc.

I doubt if there is anyone at this stage who would think that we have learned the final bit of knowledge about the nature of matter. We can be equally sure that new materials will multiply the problems of the future and that as always our engineering professions will play a large part in their solutions.

The Uneven Nature of Problems Facing Different Parts of the World Account for the Different Depths of Horizons That Each May Have

Unfortunately, every part of the world is not in the same stage of development, and problems that confronted one section 100 years ago are now facing another area.

The people of India, for instance, are struggling with terrible problems of over population and the accompanying shortage of food supply. Famines are almost a constant occurrence.

China is somewhat farther advanced and while she is not completely free of the above problems, they are currently faced with the many complexities that go with rapidly trying to industrialize their nation.

Japan is a step farther in the world's progress and they are fighting desperately to expand their trade markets.

Europe, generally, is farther along, and their struggle is to raise their standard of living. At the present stage, their chief needs are for luxury items—better homes, more automobiles, radios, television sets, phones, bathtubs, etc.

The problems that we face in America are more concerned with what you might call a need for a super deluxe luxury standard of living. Most of us want two cars, almost everyone has more than one radio as well as television sets. A home isn't really modern unless it has two bathrooms. Power lawn mowers are commonplace. Our whole life complex is geared at this level, and the number of nice things available increases each year. The volume of these create more problems for us than almost any other nation. Of course, we can all be thankful that the nature of these problems are not of the famine type, but rather of the kind that create opportunities for the engineers of our day.

I do not mean to imply by this brief resume that these are the only problems faced by different sections but only to emphasize that they vary in number, in complexities, and seriousness. Indeed, the fact that they are different creates a good many of the world tensions that we now face and contributes largely to many of the legal and defense difficulties that concern all of us.

Another Characteristic of Problems is That They Vary in Type With the Stage of Development of An Industry

In a one man shop, the owner makes his goods, he is the salesman, the financial expert, and, of course, the recipient of any gain or loss from operation. Problems faced can be handled by this one man because they are not great in number. However, as the enterprise grows into a small company he must add to the management layers to handle the increasing volumes. Many new problems now face the man who owns the company. All of the original problems are still there plus many new ones, such as getting things done by others.

The large corporation has many layers of management, and many staffs to assist them, such as Industrial Relations, Purchasing, Accounting, Industrial Engineering, etc. This, of course, is caused by the volume of problems in many different areas growing to a point where it requires specialized skills to handle them.

Here are three different situations all having some of the same problems but with the small corporation having problems that are yet to come to the individual enterpriser, and the large corporation having problems that are yet to come to small corporations.

Solutions of Many of These Complex Problems Mean That the Industrial Engineer's Horizons Will Be Greater in Areas That Are Now Perhaps Hazy But Certainly Perceptible

Automation is such an area, for while the Industrial Engineer has played an important part in stimulating the concept and assisting in the actual mechanics of installation, the job is not yet complete. Several important installations have failed because an inadequate job was done of designing the whole system.

With the high investments in equipment and material of automated work, a much better job of integrating men, materials, and machines must be done.

Another hazy area that we ought to get some answer for before the problems become more acute is a study and reappraisal of working hours and skills. These horizons will have to expand to keep up with all of the other dynamic changes in industry. A change is taking place in the trade skills required to run and maintain these automatic production systems. Greater training in electronics, servomechanisms and perhaps data processing equipment is becoming more necessary.

In the past, the Industrial Engineer has not played a prominent part in the design of product, but as greater and greater investments in equipment are required the product will have to be designed to match the increasing complexity of the processes. Again, this is something that can offer great potential for Industrial Engineering effort. The staggering amounts of capital necessary on these systems will force an extremely careful analysis of how it is spent. The future value of money must be considered in light of long term planning, the dangers of obsolescence, changes in consumer habits, growth of competition, etc. It would be well to look a little ahead and anticipate these problems and to be prepared.

Another area is the growth of staff and service personnel. These people are beginning to outnumber the production workers in many of the more advanced companies. As a general thing these jobs are not scientifically designed or analyzed. As our systems grow more complex, this trend will continue. The intelligent control of this growth may well spell the success or failure of the organizations of the future. How to do this may be hazy, but the need is glaring. There may be services not known heretofore; such as nuclear energy, electronic data processing, mathematical solutions, communications such as T.V. and radio-telephony, etc. For the most part these are salaried jobs which tend to be fixed costs, which is another powerful reason for learning more about them and how to measure them. The conventional Industrial Engineering measurement tools may not be adequate for this and brand new ones in all likelihood will be necessary.

Decision requirements on the part of all levels of management become more complex. A decision on part of an integrated system will be extremely difficult. More and more of these decisions will have to be made in terms of the effect on the whole system. In many instances only the output of simulations from electronic data processors can furnish enough intelligible data for managers to even dare to decide on a course of action.

All of these changes are having, and will continue to have, an even greater effect on the people that operate our business enterprises. For years in the field of methods work we have studied the physical requirements of jobs. The whole theory of motion economy evolved from these studies.

While this information helped a great deal in keeping tasks in bounds and is capable of being effectively performed by human beings, it does not answer many of the fatigue and tension problems that arise on modern day jobs. On many of the automated jobs people lose a sense of accomplishment, boredom can be high, and responsibility is high because of the great volume of products that are turned out each day. All of these cause fatigues and tensions about which very little is known.

Our horizon had better widen to the point where, as we design these complex systems, we can extend and build more data on both physiological and psychological requirements of the people who will operate them.

Up to this point I have talked about problems, their characteristics of increasing geometrically, the different levels of problems across the world and in different kinds of industries, and how we increase the frontiers of our engineering know-how as they are solved. However, these are only the problems that we know about today. Let us look ahead a little and see what they might look like five or ten years from now.

Future Horizons That Are Not Even Hazy and Some Possible Problems for the Engineers of Tomorrow

The growth which our country and the whole world is experiencing will bring many and complex problems to us that are very difficult to even visualize.

A group of government economists in Washington are responsible for the following data. Our present population of approximately 180 million people is estimated to grow to approximately 200 million by 1965. The number of married couples is estimated to increase by approximately 8 million.

The labor force will increase by approximately 25%. There will be many changes in its make-up. The number of women in proportion to men will increase, the average age will probably drop, and there will be an increase in the number of part-time workers. The shortage of scientific and professional personnel will continue to be critical.

Gross national product will go from 436 billion dollars per year to 570 billion, personal income from 357 billion to 450 billion, and employment from 65 million to 76 million by 1965 and to 97 million by 1970.

These men looked a lot further ahead than 1965, but the figures become so astronomical that they are almost beyond comprehension.

The same sort of growth in population is occurring in the rest of the world and particularly in those countries where the living standard is relatively low. The international problems arising from these circumstances are extremely serious and will affect the entire world. These economists predict that the total world population will increase from 2½ billion people to 3½ billion by 1970. Contemplate for a moment the terrific impact that growth of this kind will have on the economic and social structures of the world.

Just producing enough food for this number of people is going to be quite a task. One of the very serious problems in this connection will be the supply of water. While there is plenty of this life sustaining commodity, it always seems to be located in areas that are not well adapted for year around production of food, or it is in an unusable form such as sea water.

There are many interesting engineering problems that will develop along this line. In a dream stage, at least, is a consideration to run a pipeline from the Great Lakes to the arid Southwest. Think of the new industries that this could create. Another fascinating experiment which holds great promise is one that reduces the surface tension of salt water so that it can economically be converted to fresh life-giving water. The development of cheap power is a must in this connection, and a good deal of research is going on in this area.

The future holds many interesting developments in other fields as well and all, of course, will bring many new problems for the engineers to solve.

As a result of the space explorations, we will probably have more accurate weather forecasting and perhaps some day a modest control of weather. The implications of this on all business enterprises and professions can be profound.

Improved world communication is almost certain to result. Our scientists can foresee static free, high quality, uninterrupted and economic radio and television transmission all over the earth.

Rocket transportation anywhere on the globe and to other planets is just around the corner.

The discovery and use of exotic fuels such as boron and nitrogen compounds in rockets place them only a step away from everyday use in the more conventional forms of transportation.

Whole new industries will be formed and a great many old ones altered to take care of these advances.

The developments taking place in harnessing solar energy, new chemical batteries, nuclear and thermonuclear power generation, use of winds and tides for power generation, and generation of electric power without going through heat transfer and rotating machinery are wonderful to contemplate.

These are developments that are bound to take place, and they will perhaps be able to help supply the necessities and luxuries which the expanding population of the world will demand. All of these problems are certainly going to change the face of our activities in the future, and they do emphasize the urgent need for better long range planning.

We will have to try to picture these changes so that we can estimate future customer requirements, business opportunities, and to evaluate possible competing products and systems of the future.

It is not necessary or practical to wait until these problems arrive. We can plan what this future environment will be like by synthesis. This would involve broad scale physical feasibility studies, preliminary system designs with reasonable allowance for flexibility so that as actual data is collected the systems can be practically modified. Just starting such studies is of great value for, as information is fed back to management, it stimulates new concepts and improvements. Above all, such synthesis provides the means of evaluation.

All of this has a familiar ring for what it is pointing up is the use of applied operations research techniques such as simulations, regression analysis, correlations and above all, a liberal use of imagination.

Of one thing you can be sure—the future will not be free of problems. You can also be sure that this future will materialize as fast as the engineers of the world can meet the challenge of these problems. Our horizons will expand beyond the dreams of most of us.

This conference is devoted in a sense to this kind of thinking. Problems at several different levels of Industrial Engineering development are being presented and with the solutions which the engineers know about today. You can attend sessions that are at your present problem level and share the experiences of others. This is always a rewarding experience for it reassures you that you are not alone, and that solution is possible and practical.

It can be even more stimulating to look in on some of the problems that are beyond your present stage of development.

A great deal has been said about the change that is taking place in the Industrial Engineering profession, and all these problems of the present and the future certainly indicate why that change is taking place. In this view, the practice of Industrial Engineering has probably changed more in the past ten years than any other branch of engineering. The present level of practice probably varies more than any of the others. Some companies are still doing Industrial Engineering work at the level of rate setting, while others are completely up-to-date and are using in their everyday work the techniques of operations research on their expanding problems.

Our educators have been pretty good visionaries for they started sometime ago to better equip the graduating engineer to cope with these problems.

The future need for more and better Industrial Engineering is as certain as our very presence here today. There is a great unrest in the field. I find everywhere an avid desire for more knowledge and a great many of you are busy acquiring it through both practice and education. As advanced as some of the modern techniques are at this point, they will be inadequate for some of these problems of tomorrow. Therefore, it behooves all of us to have a great deal of curiosity, to do some research of our own, and to sponsor it in others to develop even newer techniques and ways of thinking that will be useful in the complex world that is coming.

This is one of the great advantages of belonging to a professional group such as the American Institute of Industrial Engineers. The very fact that we can organize a conference of this kind makes the world know that as a group we recognize the existence of these problems, and that we either have the know-how or we are willing and able to acquire it to help solve them.

These, then, are the problems that you will be facing tomorrow of which it would be well to have some advance knowledge.

The presentations of the research group are looking as far ahead as present day technology has advanced. Do not sell this group short, for I am certain that the thinking that they are doing now will be commonplace in from five to ten years from now.

There is a real challenge for us as Industrial Engineers in these developments, and it is well portrayed in the definition of our profession.

We will be the engineers that design these new systems so that they are practical; our function is the one that must integrate the men and women with the exotic new materials and equipment of the future. Ours will be the job of specifying the needs and predicting which course of action to take, and to do some pretty careful evaluation of these courses of action.

Regardless of the width of your horizon now, there are sessions here that will be presented that will certainly enlarge them. I wish all of you a stimulating and productive conference.

SOME ECONOMIC ASPECTS OF DECISION MAKING IN PRODUCT DIVERSIFICATION

by **DR. ERNST W. SWANSON**
Senior Research Economist
INDUSTRIAL DEVELOPMENT BRANCH
ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY

A graduate of the University of Chicago with a Ph.B. in 1930, a Ph.D. in 1940, Dr. Swanson has had a long and active career in Business Administration and Economics.

From 1934-41 he was a professor of Business Administration at Drake University and Washington State College, then from 1941-44 he was the principal fiscal analyst in the Bureau of the Budget, Washington, D. C. From 1944-47 he was Research Economist and Assistant Director of Economic Research for the U. S. Chamber of Commerce, and from 1947-48 Professor of Economics at Butler University.

In 1948 Dr. Swanson became Professor of Economics at Emory University, Atlanta, Georgia. He held this position until 1956 when he became Senior Research Economist at the Georgia Tech Engineering Experiment Station, the position he now holds.

Dr. Swanson has, since 1940, been editor of the *Southern Economic Journal*, and since 1943 Interim Consultant for Lockheed Aircraft Corporation, Georgia Division.

He is the author of numerous articles and pamphlets on economic problems and theory and is listed in *Who's Who in Commerce and Industry*, *Who's Who in America*, *Who's Who in the South*, and *Who's Who in Statistics*.

SOME ECONOMIC ASPECTS OF DECISION-MAKING IN PRODUCT DIVERSIFICATION

by Ernst W. Swanson

Industrial Development Branch
Engineering Experiment Station
Georgia Institute of Technology

THE GENERAL PROBLEM

THE Southern Furnace Company is considering going into the manufacture of a propane gas-fired furnace for the provision of store, industrial, and power-plant heat. It now manufactures coal—and fuel-oil-fired furnaces, but with the recent improvements in the distribution and shipment of propane gas, there is a possibility of an expanded market for its products. The Company thus seeks to learn whether it should expand its product base, i.e., diversify.

The manufacture of this new product, even though it falls within its present field of activity, may change significantly the firm's uncertainty pattern. The degree of change (+ or −) is dependent upon the amount and nature of information about the product and its cost and market. Change under uncertainty conditions determines the level of risk of loss of income that might occur, and the risk is a function of the probability of making a wrong decision. The right or wrong decision is based upon the information available or to be developed. Obviously, the true answer cannot be known but it may be approximated.

The action to be taken on whether to diversify or not is a result of the criteria governing the Company's behavior and, in turn, their relationship to the information. The action can be stated as a function of the information. Thus, where A is action and x is information:

(1) $A = f_1(x)$.

As a rule, there are several ways of doing something (Actions). The final decision is made to rest upon comparative evaluation of the payoff of the actions. If P is payoff, then

(2) $P = f_2(A, x)$.

To be sure, if there is a cost to the collection of the information and its analysis, a more accurate evaluation than given by equation (2) may be derived from this equation:

(3) $P\text{-}C = f_2(A, x) - f_3(A, k)$, where cost, $C = f_3(A, k)$.

Since x does not give the true answer, equation (3) can only be stated as a probability, the expected net payoff. The firm seeks to maximize equation (3) on this assumption.

THE PROBLEM OF COSTING

The competition faced by the Southern Furnace Company is of two kinds: First, and most significant, perhaps, is price (or cost) competition. Thus, the price of the heating unit influences the cost of the energy or heat through the rate of depreciation of the equipment that is set up by the purchaser. Associated is the price of the fuel used in the furnace. Second, competition arises from product quality differences. Furnaces fired by propane gas offer certain technical advantages or disadvantages over furnaces fired by coal or fuel-oil. Compared with gas, coal or fuel-oil present ash or air pollution problems.

Hence, in an evaluation of the overall features of the different units, price and quality must be considered. Economic and technological elements both are to be assessed.

The provision of cost data, as a rule, assumes sizable significance in the economics of diversification, largely because new products or new processes may be involved. Although the company is experienced in producing other furnaces, this experience may not be broad enough to supply all the essential cost and technical data. In other words, past experience is not enough to yield estimates of costs which would be operative had the gas furnace been in production for some time. Data must be approximated in terms of experience that is not wholly directly related to the manufacture of gas furnaces.

Two ways of meeting this difficulty are possible:

The first involves estimation of costs of each furnace component according to the experience had on the working of comparable metals in other related products of the firm. The total of the costs so derived plus a margin to cover overhead and profit would yield the cost or market price of the furnace.

The second is essentially the contrary of the first, Because the purchase price of the furnace to the customer must be set at a competitive level, the process of costing departs from that cost per unit of heat that is considered competitive and the capitalized value of the investment element (the outlay for the furnace) of this cost is derived as the approximation to price.

Of the two methods, the second possibly comes nearer to a solution of the problem because it goes out from the approximate competitive price. Both methods could be applied, the one to supply a check upon the other. The second method is developed here since it offers the greatest difficulties.

ELEMENTS IN COMPETITIVE PRICING

The following steps are taken in the costing by the second method—here termed, competitive pricing:

First, the cost per unit is derived.

A. The present cost (price) of the heat (per million Btu's) is established. Heat is the end-product of the furnace.
   1. All costs of producing heat are charged to an aggregative account. The following costs are included: depreciation and interest (capital costs); direct labor, fuel, and supplies (operating costs); any plus or minus differences in indirect labor; any plus or minus difference in overhead; any incidental expense due to smoke abatement law enforcement; and special fuel charges as storage, transportation, etc.
   2. The direct costs are assumed to vary with the hours of day of furnace operation and should be computed at 8-, 16-, and 24-hour levels.
   3. To avoid complicating the solution too much, the assumption is made that the furnace when in use operates at all times at optimum output.

B. Next, the expenses are allocated over the year according to the hours of operation of the heating unit.

C. Finally, the total expense is divided by the heat output (Btu's) for the time period. The result is the price or cost per Btu. This result may be stated per million Btu's.

   This method may be generalized:

   Let c = capital cost, stated as yearly depreciation
   i = interest cost per year
   L = direct labor cost per year
   l = indirect labor cost per year
   f = fuel costs per year
   e = incidental expense per year: smoke abatement cost, storage cost for fuel, ash disposal, etc.
   p = price (cost) of heat per million Btu's
   o = output of heat per year; millions of Btu's

   Hence:

   (4) $p = (c + i + L + l + f + e)/o.$

The competitive price may be stated mathematically:

A. Find I, where I is the investment element that leads to the expenses c, f, and i.

   Variables c and f are perhaps the two most important variables that determine the competitive strength of the new furnace vs. the old. Under nearly all circumstances, e may be considered next in importance. L and l may prove to be the least significant.

B. I can be said to be a function of the cost of the various components of the furnace: the burner, the mixer, the "pot", the boiler, etc. But some of these costs are at this point fairly indeterminate. Hence, I may be said to be fairly indeterminate.

C. One observation is nevertheless certain. I must be small enough so that over the life of the gas furnace, c (= I/time) approaches c for any other source of heat plus savings, plus or minus, that may accrue through the use of the gas furnace. This cost would of course depend upon the level of output of gas furnaces, the state of their production technology, and the learning curve selected to represent the expected production capability.

   Once total I is determined, the I for each component part of the gas furnace may be approximated.

D. To derive I, when costing by components is not possible, the following method is suggested:
   1. Establish first how much of the costs in the current price per million Btu's can be allocated to I and "blow-up" this figure to total I. The applicable costs are usually c, i, L, l, f, and e.

      All of c and i are clearly chargeable to the I account. Distinct savings in the other costs are all debited to I. In the case of f, there may be savings in the use of gas over coal or oil, in the long run price, in the investment in storage facilities, in fuel and ash handling, and in the interest on stock-pile values of coal or distillate. In the case of e, there will be no need to install expensive smoke abatement equipment, to truck away cinders, or to dispose of stock accumulations.

(4) D. 2. The blow-up is accomplished by capitalizing c, i, and the savings in l, f, and e.

This capitalization is permissible on either of two assumptions: (1) that the change to propane gas will be relatively permanent and, hence a permanent capitalization of the costs is possible; (2) that the change to propane gas, while relatively permanent, may not warrant the assumption that all of the savings will be permanent. A rise in the efficiency of use of other fuels may lead to cuts in savings. Hence, the capitalization period may be limited to say 15 or 20 years.

This capitalization may be performed through the formula which states the present value of a series of payments (the total savings) be continued indefinitely·

(5) $a_n = \frac{1 - v^n}{i},$

where v^n is the present value of the nth payment and i is the rate of interest. The rate should approximate the current market rate for such period borrowings as are involved. For a perpetual state $n \longrightarrow \infty$ and $v^n \longrightarrow o$., the expression then becomes $1/i$. The savings are multiplied by $1/i$ to yield the equivalent I.

The capitalization of the above values may now be derived:

(6) $a_n = (c + i + dL + dl + df + dc) \times \frac{1}{i}$,

where d now stands for the differences in costs of the other fuels over the propane gas.

These differences may be plus or minus.

CAPITALIZATION AND THE ORIGINAL COST OF THE GAS UNIT

The capitalized value obtained by equation (6) is the amount that the customer can afford to lay out for the propane gas facilities, given his present price of heat per million Btu's. This value reflects the competitive price for heat, per million Btu's. It is doubtful that the Southern Furnace Company can approach this value in its early stages of production of the gas unit.

To derive the possible original cost of the unit, the formula for cumulative average cost of the learning curve is inverted as follows.

$\log A_x = \log C_1 - k \log x$, where

A_x = cost of the xth unit

C_1 = original cost, the cost of the first unit produced and

k = slope of learning curve at a given percentage.

Solve for $\log C = \log A_x + k \log x$. See Appendix 1 for Table of k.

To illustrate, assume that $c + i + dL + dl + df + dc$ for a given firm now using fuel oil heat total $33,300 per year. Capitalized at 5% this amounts to $666,000, the possible investment in a new gas unit.

Now, make the further assumption that this outlay would be equivalent to the price of the 100th gas unit of this type that would be produced by the Southern Furnace Company. To get the original cost, assume that an 80% learning curve is applied. Then

$\log C_1 = \log \$666{,}000 + 0.3219 (\log 100)$

$= 5.8235 + 0.6438 = 6.4673$, or

antilog = $2,933,000, the original cost which supposedly includes research and development outlay.

This last figure may be regarded as a guide to administrative decisions. It is the cost that reflects the competitive price currently applicable. The Company cannot expect to sell the new heat units at this high price. But it does show (1) what the Company must expect to start with, and (2) that until experience in engineering and production brings down the cost, a number of units will be sold at a loss. Hence, it makes possible profits prediction, on the assumption that the 80% is appropriate. It is conceivable that a lower curve is applicable; whether this is possible must be determined on the basis of past experience with other developmental activities in comparable product lines.

MEASURING PROFIT POTENTIALS

The profit potentials may now be determined through the development of a Measure Of Effectiveness (MOE).

For the Company an incremental present value of project return is to be computed. This value may be defined as the present value of the expected gross return from sales of gas furnaces *less* the expected costs of manufacturing *plus* the expected present value of the scrap value of fixed and working capital necessary to furnace production.

This general theory is stated in another way by Paton (Advanced Accounting): the incremental present worth of the project is the extent of the increase (or decrease) in the value of the assets and accumulated profits above (or below) that which would be gained if the capital were invested in marginal undertakings. Its adaptation is as follows:

A. The incremental present value of all possible projects by types of gas furnaces and selected learning curves would be derived and compared. Computations would be made for different time periods as well. Joel Dean would say that capital budgeting is involved. For each possible type of gas furnace and its expected gross return (or sales) and cost, an incremental present worth of the undertaking is to be derived for both short and long time periods.

B. The following symbolic structure is constructed for measuring the present value:

$S_1, S_2, \ldots S_n$ = present value of expected sales during 1st, 2nd, and nth years after production is begun.

c = sum of non-variable costs, \$/year

c_t = capital charge rate on tangible assets, \$/year

c_f = fixed capital charge rate, \$/year

c_r = capital charge rate on recurring investments, \$/year

c_w = capital charge rate on working capital, \$/year

d = number of years over which capital is depreciated

E = operating expenses (fixed and variable)

$f_d = \left[(1+r)^d - 1\right] / (r)(1+r)^d$

t = income tax rate, fraction/year

$f_n = \left[(1+r)^n - 1\right] / (r)(1+r)^n$

1 = variable expenses that are a function of output, o

$f_s = 1/(1+r)^c$

i = return on investment

$= (1+r)(1+W/I)^{1/n} - 1$

I_t = investment in tangible assets, dollars

I_i = investment in intangible assets, dollars

I_f = total investment in facilities, dollars

I_r = investment of a recurring nature, dollars

I_w = investment in working capital, dollars

m = life of recurring asset having a life less than the project life

n = number of years assumed for life of project

n_r = number of years of useful life of recurring type assets

p = construction and developmental period, months and/or years

q = probability of failure of project

$1 - q$ = probability of success of project

r = market rate of interest for given types of funds

S_e = tax exempt sales, dollars

S_t = taxable sales, dollars

s_b = expected scrap value at beginning of projects, dollars

s_e = expected scrap value at end of project, dollars

V_s = present value of sales, dollars

V_u = present value of project, dollars

V_f = incremental present value of project, if it fails; dollars

V_s = incremental present value of project, if it succeeds; dollars

C. The Restrictions

Certain restrictions must be placed upon the model to keep it within reasonable bounds. Among these are:

1. Income after taxes is made available for investment only at the end of the fiscal year. This is not realistic since it is actually available on a relatively continuous basis. But the computations are not too significantly different from a continuous compounding.
2. Revenue, expenses and annual tax credits flow in or out uniformly, year to year. Some of the terms to be included in the MOE will not abide by this condition in all situations; e.g., tax-exempt revenue.
3. Even though it is actually relatively committed continously, all of the capital required for the project is committed at the beginning of the construction period.

D. Given the symbols and the restrictions the MOE is now derived. Each product is regarded as representing a possible project.

1. For any project there is a fundamental MOE:

$V = S - E$, where

$S = (1-q)\left[S_e + S_t\ (1-t)\right] f_n$

$E = \left[C + 1 + \Sigma I_c\right] f_n$

I_c = capital outlay x the depreciation factor

$V = (1-q)\left[S_e + S_t\ (1-t)\right] f_n - \left[C + 1 + \Sigma I_c\right] f_n$

The MOE measures the net profits. It is a simplification and it applies in general to any one of the heating units contemplated for production and sales.

2. As already developed, the first several of a series of outputs of the particular product will be sold at prices too low to yield revenues sufficient to cover E, especially the fixed element, c. Hence, for some time profit would be minus, and the present value of the net figure is deducted.

Moreover, profit clearly is a function of the degree of market penetration. Hence C, sales, are a function of the sales efforts of the sales department of the Southern Furnace Company. To be sure, the degree of market penetration also varies with product differentiation; because of specially built-in qualities and characteristics, some products can be identified more readily with

Southern Furnace Company than can others. Hence, the growth of profits would differ for different products.

3. The above MOE may be expanded upon to give effect to taxes, varying rates of depreciation for the several possible classes of capital, and tax credits. A generalized formula follows:

$$V_s = \left[(S_e - E)f_n + (S_t - E)(1 - t)f_n\right]$$

II

$$- \left[(1 - t)f_n \; \Sigma(I_r \cdot \frac{c}{r} + I_t \cdot \frac{c}{f} + I_w \cdot \frac{c}{w})\right]$$

III

$$+ I_1 t + \sum_{n>m} \frac{I_r t f_n}{r} + \sum_{n>d} \frac{I_t t f_d}{d} + \sum_{n\leq d} \frac{I_t t}{d} \left[f_n + \frac{d - n}{(1 + r)^n}\right]$$

3. Part I treats (1) tax exempt reserves for which there may be or may not be any expenses, (2) taxable reserve, and (3) operating expenses.

   Part II treats the present values of the capital charges on recurring investments, permanent investment, and working capital, and

   Part III treats

   (1) the present value of the lump sum income tax credits on intangible investment,

   (2) annual tax credit on capital items whose purchases recur,

   (3) annual tax credit on capital with an accelerated depreciation rate,

   (4) annual and lump sum tax credits on investments in assets with a long-term depreciation rate.

A DIGRESSION ON THE PROBABILITY FACTOR

In the determination of S and V above, the factor 1-q, which gives the probability of success of the venture, would have to be determined. This determination is by no means exact, and the probability theory behind it needs, therefore, to be reviewed. Time permits but a sketch of the theory.

In business decisions the concern is usually with unique or approximately unique choices or propositions. The frequency theory as espoused with variations by von Mises, Reichenbach, Feller, Cramèr, and others, considers probability as the limit of the outcome of a large number of alike trials. This definition is acceptable only to our purpose if a certain application of frequency theory can be made.

If the writer of this paper has not misunderstood their propositions, most frequency theorists—with possibly the exception of Reichenbach—rely on a priori propositions or principles which cannot be refuted by the empiricism of the applicable field of knowledge. The axiomatic approach of von Mises, Kolmogorov, Feller, and Cramer may, in fact, attest to this nature of probability.

At the same time, it must be recognized that probability does not belong to a given event itself, but only to the event as representative of a class of things. When we say that it is probable that XYZ Corporation will fail or succeed in an undertaking, Reichenbach and, long before him, von Meinong would say that this proposition has nothing to do with probability in the frequency sense. Yet, if there is a rational relationship between the proposition and a state of business affairs on the evidence submitted, there is a probability involved.

What we mean is that the proposition is probable relative to our knowledge about business affairs and, especially, the kind that is appropriate to the given situation. In this respect, as it is for that matter in all situations, probability is a problem of degree. We seek to give this acceptance credence by finding a criterion which will help us state whether some choice or proposition is more or less probable. It says in effect that one group or class of premises is more probable than another if it yields the larger number relatively of true findings. By the same token, an unique proposition is more probable than not if the bulk of the evidence supports it. But this we must also recognize: that in seeking confirmation of a proposition through repeated trials we still depend upon given principles and prior knowledge in collecting our data — Reichenbach notwithstanding. *No amount of repetition is sufficient to yield an absolute certainty or a determinate probability.*

To those who insist that the probability of an unique choice or proposition is but an individual case, there is an alternative view. If we have collected evidence relative to the single situation, it will apply to any other situation comparable or similar to ours. *The probability has to do with certain aspects of the situation that are inherently applicable.* And, having gotten this far, we can ascertain (even guess) the relative frequency without having evidence as to its value.

However stated, frequency theory cannot be made to rest merely on relative frequency. Probability is not only linked with frequency but it is also associated with the manner in which the frequency is evaluated; as some, the subjectivists, might say—how the decision-maker conceived and analyzed the situation to which a given frequency has been made to apply. To follow John Dewey, the probability about a proposition has meaning when and only when it leads to decisions that work. And whether they work or not depends upon the nature of the predictional structure evolved by the decision-maker and upon how he uses within this structure the evidence gathered to derive the probability. We need in effect to know something about the prior knowledge foundational to our judgments about frequency.

Equally as essential as the predictional structure is the extent of the efficiency of the classification by which we categorize the choice or propositions. We need to set the outcomes of the various alternative choices in such compartments that the probabilities of each are relatively distinguishable. The effectiveness of choice is dimmed by the lumping of frequencies without concern for the discreteness of the classes too often subsumed in the major term of the argument. We need separation of the individual probabilities, not aggregation, to get at an unique choice.

Counting alone cannot tell us what portion of the universe is embraced by our finite group. Instances *in themselves* do not render a determinate probability. We need in addition to establish that a proposition has a greater probability than any other proposition derived as a possible problem solution or as of consequence to a decision. We attain this purpose by demonstrating that it obtains in a greater number of similar cases—*note: "similar," not necessarily identical.* There is no need for identity in most business situations. Oftentimes, however, a few instances will have greater weight in decision making than will a much larger sample, largely because the many instances may be many only because of aggregation. Because we do not know the conditions (prior knowledge) governing a situation, we almost instinctively seek to offset by taking a large number of observations from the universe of supposedly comparable situations rather than seeking to classify more adequately our observations. A large sample need not be as revealing of the true proposition as may few observations governed in their collection by the critical mind.

Therefore, if we take the concept of frequency sketched above and couple it with a good predictional structure, the derivation of a numerical value of chance of success, 1-q, or failure, q, seems possible, even for an unique choice or proposition. We shall not debate here whether we thus treat a frequency ratio or a degree of belief.

COMPARISON OF THE ALTERNATIVE INVESTMENT POSSIBILITIES.

1. The MOE's would be derived for each of the proposed products: store-office building, industrial and power plant furnaces. Then a comparison of the three MOE's would be made to determine which of the three proposed products should be produced and marketed. The questions are: Which product has the greatest long-run potentials in the way of profits and growth in the profit rate? Which has the greatest short-run potentials?
2. Obviously, a number of assumptions as to the rate of growth of sales and, hence, the expected profit rate are possible. The profit rate may be defined as the ratio of average annual expected profits to the average annual investment in total assets, recurring and "permanent." These are selected:
   a. For the ensuing five years growth is expected to average out at the same rate as the average annual rate of the United States economy since the 1880's: three per cent.
   b. For the ensuing five years growth is expected to average out at the rate experienced in recent times for a number of producers' durable goods: five per cent.
   c. Or, take an extreme assumption that the rate will be 10 per cent.
3. Two additional questions should be raised:
   a. How probable is the *"most probable"* forecast?
      Rather than introducing a probability coefficient into the MOE's, a probability coefficient may be assigned the growth potentials. This makes possible placing the decision on the best product in a game matrix—"best" in mini-max sense.
   b. How probable does the *"least likely"* prospect have to be before the return on the most conservative investment alternative may be adjudged equal to the return on the most non-conservative alternative?
      What we seek is the point of indifference in probabilities, given the rates of return on the investment alternatives.*
      To answer question (a), how probable is the "most probable" forecast, strictly arbitrary choices may be made. Since there are three products we may, as a beginning, assign equal values of 0.33 1/3 to each estimate of the profit rates for the three rates of growth.

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*The attempt here is to maximize or optimize the expected utility under conditions of uncertainty. Reference is to Howard Raiffa and R. D. Luce, *Games and Decisions* and M. Friedman and L. J. Savage, "The Utility Analysis of Choice Involving Risk," *Journal of Political Economy* (August, 1958), 279-304; and Jacob Marschak, *Rational Behavior, Uncertain Prospect and Measurable,* a Cowles Commission Paper, New Series, No. 43.

Derivation of the indifference probabilities for (b) may not be done so readily. A possible approach is, however, as follows:

Let A stand for the 3 per cent rate of growth
B stand for the 5 per cent rate of growth
C stand for the 10 per cent rate of growth

Assume, next, that the rates of return for each furnace and rate of growth are:

MATRIX I

$$\begin{array}{lccc} & A & B & C \\ \text{Store furnaces} & a_1 & b_1 & c_1 \\ \text{Industrial furnaces} & a_2 & b_2 & c_2 \\ \text{Power-plant furnaces} & a_3 & b_3 & c_3 \end{array}$$

Now, to start the decision process, assume that power-plant furnace sales will not experience the high rate of growth, 10 per cent. Assume, furthermore, the return therefore at 3 and 5 per cent rates is too low, relatively speaking. Then the indifference probability can be computed for the industrial and store-office building furnaces as follows: Let

(1) $a_2A + b_2B + c_2C$ = the return on the industrial furnace, and

(2) $a_3A + b_3B + c_3C$ = the return on the store furnace.

Then, the return on the industrial furnace will be the same as the return on the store furnace when

$$a_2A + b_2B + c_2C = a_3A + b_3B + c_3C. \quad (3)$$

Solving (3) in terms of A, where A stands for the indifference probability for the low rate of growth, we get

$$a_2A - a_3A = b_3B + c_3C - b_2B - c_2C \quad (4)$$

$$A = \frac{B(b_3 - b_2) + C(c_3 - c_2)}{a_2 - a_3}$$

Thus, if the estimated true probability of a 3 per cent rate of growth, 0.33 1/3, is greater than $\left[(b_3 - b_2) + (c_3 - c_2)\right] \div a_2 - a_3$, the combined estimated probability of the 5 and 10 per cent rates, the store-office building furnace would produce the best pay-off.

If, however, a 10 per cent rate of growth is deemed highly probable in the years following 1965, the plant and equipment may be later adapted to the production of power-plant furnaces. Obviously, profits could be quite generous at a 10 per cent rate.

IN CONCLUSION

Decisions on diversification are among the most difficult to make. Experience shows that, as a rule, business firms err more often in this area than in others. The hope is that the above presentation on method will pave the way for the formulation of a relatively rigorous decision-making process in diversification.

Appendix 1

Table of Tangents for Selected Percentages

Percentage	*Tangent k*
60	.7370
65	.6215
70	.5146
75	.4150
80	.3219
85	.2345
90	.1520
95	.0740

INC.

section 3

INDUSTRIAL APPLICATION OF MEMOMOTION

by **SAMUEL W. EARLE**
Manager
INDUSTRIAL ENGINEERING DEPARTMENT
UNION CARBIDE CORPORATION

MR. EARLE received his Bachelor of Science in Civil Engineering in 1946 and the degree of Master of Science in Industrial Engineering in 1948, both from Purdue University.

In 1946 Mr. Earle joined the Haynes Stellite Company, a division of Union Carbide Corporation. After holding various positions involving work in cost analysis, materials handling, methods improvement, office layout, and general Industrial Engineering, he was appointed head of the Methods Standards and Plant Layout Department. In 1953 he transferred to the Industrial Engineering Section of the Management Services Department. His present position is Manager of the Industrial Engineering Department of Union Carbide Corporation.

INDUSTRIAL APPLICATION OF MEMOMOTION

by Samuel W. Earle

Manager, Industrial Engineering Department, Union Carbide Corporation

LADIES and Gentlemen, it is a pleasure to be here to participate in this meeting and to discuss with you some of Union Carbide's work with the memomotion technique. I think we all realize that a mutual exchange of information on Industrial Engineering techniques can be advantageous to everyone.

I will present a general discussion of the application of the memomotion technique in many areas. Next will be a detailed discussion on six projects, illustrated with slides and films, including the study, analysis, and presentation of data. Finally, I will comment on and show you the equipment required for such a study. We have material to pass out for those who desire additional information concerning the equipment sources and further background in this technique. (This material is not included in the published copy of the talk, but can be obtained by writing Industrial Engineering Department, UCC Management Services, Union Carbide Corporation, 30 East 42nd Street, New York 17, N.Y.)

The question period which will close this hour may be the most important part of the discussion. Since questions are so important, it might be well to note them down as they arise to be sure we'll wind up with a good discussion period. Incidentally, to give me an idea of the sort of group we have here today, could I have a show of hands of all those who have done micromotion work. Also those who have done memomotion work. Thank you.

UNION CARBIDE CORPORATION

A quick word about Union Carbide might better acquaint you with the Corporation's activities and will assist you in understanding the role of the Corporation in helping to shape things for the future.

Union Carbide Corporation was organized in 1917, bringing together several companies with similar research and production interests. The history of some of these companies dates from the 1870's.

Today, UCC is one of the nation's large and highly diversified manufacturing corporations. Its operations extend into six fields: ferro-alloys and metals, carbon products, gases and organosilicon products, chemicals, plastics, and nuclear energy. You can see this breadth of interest places Union Carbide in a position to have a hand in the future.

Few companies are concerned with so many complex and technical operations as Union Carbide. In the plants are used processes that range between the physical extremes of heat and cold and terrific pressures and high vacuums. There are at the moment, 19 different domestic companies and divisions operating in the United States, including the U.C. International Company. In addition, several divisions of Union Carbide Canada Limited operate in Canada. We have over 70,000 employees and 126,740 stockholders. The Canadian and domestic facilities include over 400 plants, factories, mines, mills, laboratories, and sales offices. Sales last year amounted to $1,297,000,000.

The Corporation's products for the most part are unseen in our everyday life, because they are the raw materials of industry. However, hardly an item is made today that is not in some way related to products and processes of UCC.

Slide 1 illustrates the major raw materials, basic processes, industrial products and uses, and consumer products of Union Carbide, and shows how the various groups of the Corporation are interrelated.

The list of specific products is quite lengthy, hence this chart shows the way in which the Corporation products are used rather than specific things made by UCC.

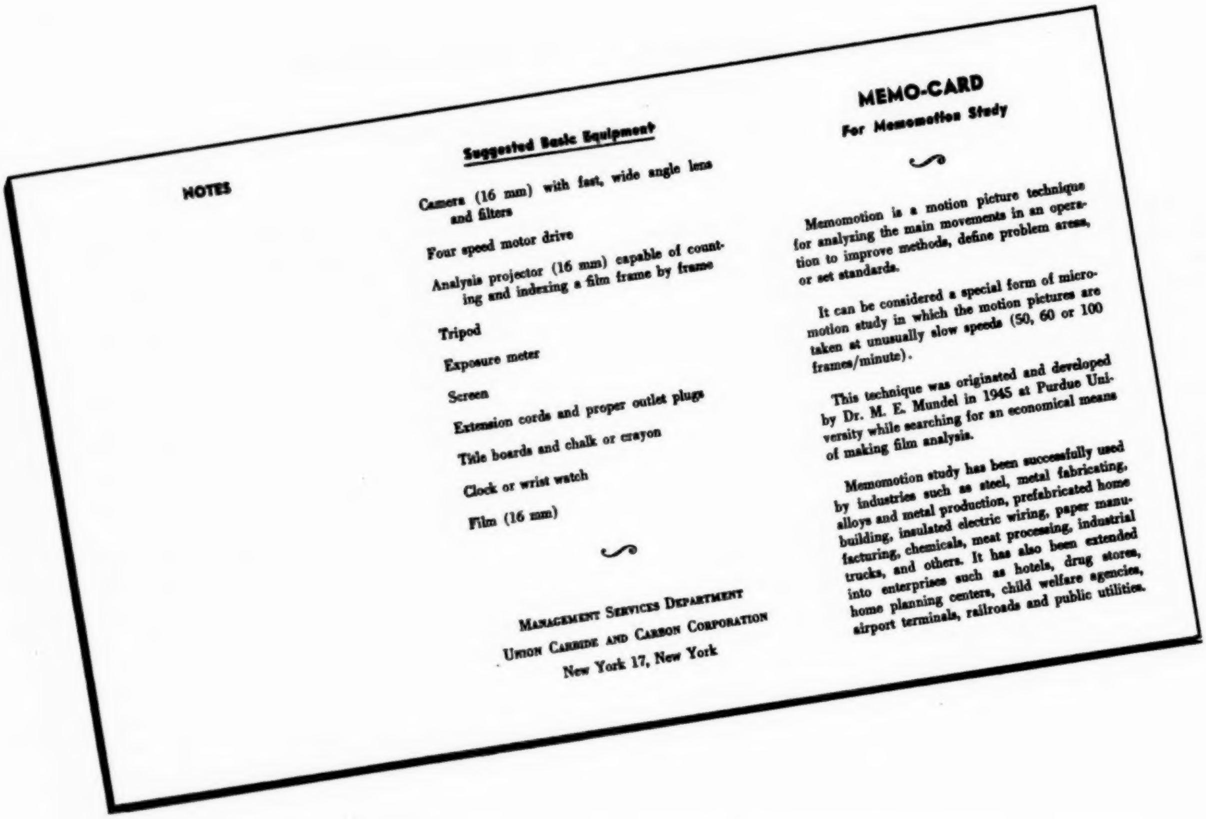
Through research, Union Carbide is constantly striving to satisfy the five basic human needs—food, clothing, shelter, health, and transportation—by developing better and new products in our six major fields.

We have copies of the booklet, "Products and Processes," available for anyone interested in more detail.

MEMOMOTION STUDY

One of the most effective Industrial Engineering analysis techniques we have found for breaking down a job is called memomotion. It allows gathering of factual data for analysis in an effective and economical manner. We have used this technique successfully in many locations and have hundreds of examples of its use in plant layout, production studies, materials handling, crew determination, cost analysis, and so forth.

Before we proceed with the discussion, I would like to say a few words about the Memo-Card which has been handed to you. Mr. Anthony Tseng has given me permission to modify and use this card



NOTES

Suggested Basic Equipment

Camera (16 mm) with fast, wide angle lens and filters

Four speed motor drive

Analysis projector (16 mm) capable of counting and indexing a film frame by frame

Tripod

Exposure meter

Screen

Extension cords and proper outlet plugs

Title boards and chalk or crayon

Clock or wrist watch

Film (16 mm)

MANAGEMENT SERVICES DEPARTMENT
UNION CARBIDE AND CARBON CORPORATION
New York 17, New York

MEMO-CARD

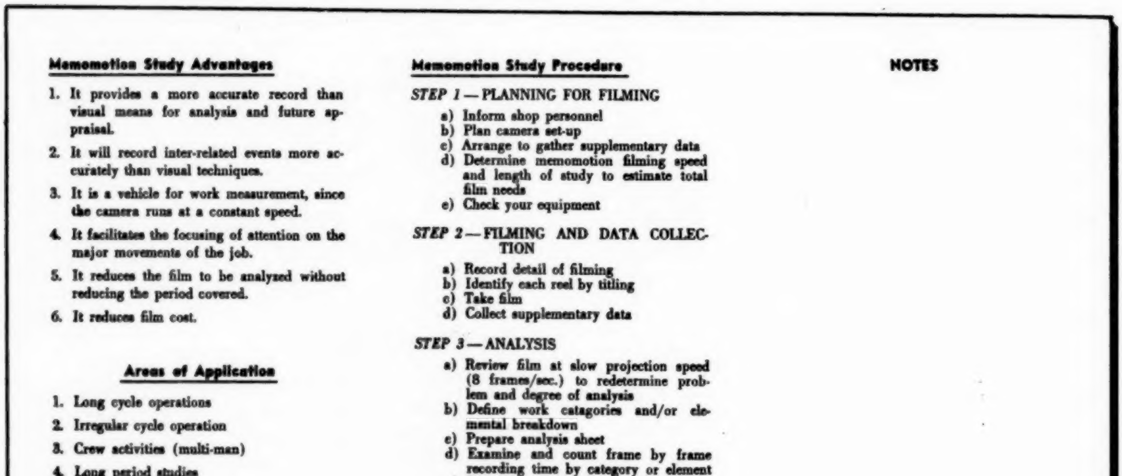
For Memomotion Study

Memomotion is a motion picture technique for analyzing the main movements in an operation to improve methods, define problem areas, or set standards.

It can be considered a special form of micromotion study in which the motion pictures are taken at unusually slow speeds (50, 60 or 100 frames/minute).

This technique was originated and developed by Dr. M. E. Mundel in 1945 at Purdue University while searching for an economical means of making film analysis.

Memomotion study has been successfully used by industries such as steel, metal fabricating, alloys and metal production, prefabricated home building, insulated electric wiring, paper manufacturing, chemicals, meat processing, industrial trucks, and others. It has also been extended into enterprises such as hotels, drug stores, home planning centers, child welfare agencies, airport terminals, railroads and public utilities.



Memomotion Study Advantages

1. It provides a more accurate record than visual means for analysis and future appraisal.
2. It will record inter-related events more accurately than visual techniques.
3. It is a vehicle for work measurement, since the camera runs at a constant speed.
4. It facilitates the focusing of attention on the major movements of the job.
5. It reduces the film to be analyzed without reducing the period covered.
6. It reduces film cost.

Areas of Application

1. Long cycle operations
2. Irregular cycle operation
3. Crew activities (multi-man)
4. Long period studies
5. Multi-machine operations
6. Plant layout and materials handling
7. Ratio delay studies
8. Irregular occurrence in a normal cycle
9. Recorded picture histories

Memomotion Study Procedure

STEP 1 — PLANNING FOR FILMING

- a) Inform shop personnel
- b) Plan camera set-up
- c) Arrange to gather supplementary data
- d) Determine memomotion filming speed and length of study to estimate total film needs
- e) Check your equipment

STEP 2 — FILMING AND DATA COLLECTION

- a) Record detail of filming
- b) Identify each reel by titling
- c) Take film
- d) Collect supplementary data

STEP 3 — ANALYSIS

- a) Review film at slow projection speed (8 frames/sec.) to redetermine problem and degree of analysis
- b) Define work catagories and/or elemental breakdown
- c) Prepare analysis sheet
- d) Examine and count frame by frame recording time by category or element
- e) Determine average time and, if desired, test statistically
- f) Correlate supplementary data with average times

STEP 4 — PRESENTATION OF RESULTS

- a) Construct standard data table and/or graphically present analysis

NOTES

to aid in this talk, to give you a summary of our present discussion, and to keep for a future reference of memomotion. This card will be referred to as we go along.

HISTORY OF DEVELOPMENT

This technique of analysis was originated and developed by Dr. M. E. Mundel in 1945 at Purdue University. Dr. Mundel was searching for an economical means of making film analysis while directing research work pertaining to various methods of improving housework. The new technique was used for the first time for research for an article, "Easier Housekeeping," which appeared in the September 9, 1945 issue of Life Magazine. The technique was used in industry in 1947.

Since its development, memomotion study has been successfully used by industries such as steel, metal fabricating, alloys and metal production, prefabricated home building, insulated electric wiring, paper manufacturing and processing, public utilities, chemicals, meat processing, and others.

Its use has also been extended into enterprises such as hotels, drug stores, home planning centers, child welfare agencies, airport terminals, and railroads. Union Carbide and some of its divisions have tried and accepted this technique as a standard analysis tool.

We will cover the following aspects of memomotion study:

1. What memomotion study is
2. Why the technique is employed
3. Areas that lend themselves to the technique
4. Procedure for making a study

WHAT IS MEMOMOTION?

Memomotion is a motion picture technique for analyzing the main movements in an operation to improve methods, define problem areas, or set standards, and can be considered a special form of micromotion study in which the motion pictures are taken at unusually slow speeds. (The Memo-Card also has this definition.)

It uses filming speeds of 50, 60, or 100 frames per minute, with an accurate time interval between pictures to provide a record for frame by frame analysis.

It is another means of performing the third step, "Breakdown," in our 8 step systematic approach to a problem.

Micromotion, you know, is used to study an operation by its detailed motions; whereas memomotion is used to study an operation by its main movements. This distinction between detailed motions, such as therbligs, and main movements is the major distinction between micromotion and memomotion study.

Now, a word about camera speeds. We can classify motion pictures into 5 types arranged in order of increasing film speed. These are time-lapse, memomotion, normal speed, slow motion, and high speed. The various types overlap and have been defined in different ways but we find these 5 classifications useful in orienting our thinking.

As Dr. Mundel states, "Normal and slow speed motion pictures are usually used where a record is desired which will permit a reasonable identical visual reproduction of an event. Such speeds likewise permit an examination of the fine details of the action recorded."[1] Normal speed photography (16 frames/second for silent film and 24 frames/second for sound film) is familiar to everyone. Slow motion (anything above normal speed) is best known as a study aid used by athletic coaches to assist in outsmarting the opposition.

Dr. Mundel goes on to state, "True time-lapse photography in which the pictures are taken at one frame per fifteen seconds, or at greater intervals, resembles work sampling in that only a sample of a series of events is recorded. In such cases, it is assumed that either the sample is representative of the whole, or that actions in the intervals between the pictures may be inferred from the picture."[2] A classic example of time-lapse is the recording of a flower being transformed from bud to full bloom. The resulting film shows this growth, captured over a period of time, in just a few seconds.

High speed movies almost stagger the imagination. Cameras are available which will handle from 32 to 8,000 pictures per second, and I understand that a German make has a top speed of 15,000 pictures per second. Such high-speed cameras are obviously for very specialized applications but they have been successfully used to study fluid flow, the operation of cutting tools on metals, and similar operations.

"Memomotion with filming speeds of 50, 60, or 100 frames per minute, with an accurate frame to frame time interval does not permit a true reproduction of a series of events nor is it a sample of the events, but it is something in between. The pictures are sufficiently close together in time so that all actions are usually recorded, but far enough apart so that the motion-time relationship is distorted when the film is projected in the normal fashion, even at very slow speed."[2]

This distortion, we shall see, of the time-motion relationship when projected is actually an advantage because it emphasizes various aspects of the activity and permits rapid review of lengthy events.

WHY THE TECHNIQUE IS EMPLOYED (ADVANTAGES)

Memomotion study is used for the following reasons:

1. It provides a more accurate record than visual means for analysis and future appraisal.

2. It will record interrelated events more accurately than visual techniques.
3. It is a vehicle for work measurement, since the camera runs at constant speed.
4. It facilitates the focusing of attention on the major movements of the job.
5. It reduces the film to be analyzed without reducing the period covered.
6. It reduces film costs to about six percent (6%) of costs with normal speed.

Advantages 1, 2, and 3, above, are common to other types of film analysis, but advantages 4, 5, and 6 are peculiar to memomotion photography. (Refer also to the Memo Card.)

Professor Richardson states, "When the advantages of filming are desired, but detail is not necessary, memomotion study provides, by a simple frame count, an accurately timed, positive record of all the variables present in the operation. Also, the film provides a simultaneous record of many of the physical characteristics of the job which are difficult to record any other way. After data have been gathered and analyzed into meaningful categories of activity, elements can be selected or discarded. Such selection is not possible by conventional means—clock or stop watch elements once selected and timed cannot be further subdivided."[3]

Explaining item 4 Tony Tseng states, "By focusing attention on the major job content, since an hour's operation can be shown in about four minutes at normal projection speed (action is extremely accelerated), non-productive movement, such as excessive walking or long delays, will be brought out more prominently than in a motion picture filmed at normal speed."[4]

Discussing items 5 and 6 briefly:

The development of this technique was motivated by the need of economy in film analysis, not only in film cost but in analysis time. By recording action at one frame per second rather than 16 per second, only one-sixteenth of the film footage is required. Analysis and data gathering time on one job ran in the neighborhood of 38 hours using the memomotion technique. A conventional method would have consumed an estimated 170 hours.

Each of the areas of application of a study must have an objective. The purpose of making a memomotion study may be:

a. To record and improve a method
b. To define a problem area
c. To set standards

AREAS THAT LEND THEMSELVES TO THIS TECHNIQUE

The application of memomotion study seems almost unlimited. It is most useful as an aid in studying any or any combination of the following:

a. Long cycle operation
b. Irregular cycle operation
c. Crew activities (multi-man)
d. Long period studies
e. Multi-machine operation
f. Plant layout and materials handling
g. Ratio delay studies
h. Irregular occurrence in a normal cycle
i. Recorded picture histories

The key word is "aid." The film only records the events and still must be analyzed.

Because of its newness, the fields of application of memomotion are limited only by the thoroughness of the engineering data required and the operating budget.

Memomotion has been used successfully to record pictorially the operation of jobs being studied so that management and/or a union could be shown the developed methods changes. Also, the technique has been used to show operational differences of two or more operators on the same job.

Application in the area of plant layout has been successful in every case. Long cycle work showing man, machine, and material movements have usually been improved through analysis and subsequent operational changes.

Work sampling studies, using a camera as the recording device, have been successfully made. In these studies electric clocks were used to start and stop at random, the motor driven camera. Mr. H. R. Thompson of the Texas City Plant of our U. C. Chemicals Company pioneered an inexpensive program timer that makes work sampling with a camera quite successful. With this technique, several hundred observations can be recorded on film without an observer present in the shop. We feel it is better, however, to work sample a film taken at one of the memomotion speeds, thereby avoiding the assumption that the recorded events are representative of the whole.

Experiments are being made on some operations which are considered normal, but have an irregular element occurring in an unpredictable manner; for example, breaks in a process machine. By using micro-switches to activate the camera when the irregular element occurs, an exact record can be obtained and analyzed at a future date.

PROCEDURE FOR MAKING A STUDY

Before discussing the procedure and showing you various examples of memomotion study, I would like to call your attention to two features:

First, we consider the camera another member of the Industrial Engineering Department. We utilize the camera to do a job where the camera is an obvious tool to gain the desired result. It is considered a working tool, not a luxury gadget.

Second, we use fast film and no auxiliary lighting since the primary purpose is to record data. Consequently, the pictures were taken with a minimum of fuss and as economically as possible. We usually get good pictures, but we do not aim for anything extra special. Many of the pictures you will see were made by people with only "Brownie" experience. After a half-hour of instruction, anyone can take these industrial movies.

Let's start by showing the difference between action recorded at regular speed and memomotion speed: First, let's look at a short strip of regular speed film (1000 frames per minute) taken by our New York staff, showing an automobile starting, driving a given distance, stopping, discharging and picking up people, turning around, and returning to the starting point.

Now, let's look at the exact same condition taken at memomotion speed (60 frames per second in this case).

You have seen 90 seconds of activity—the latter two examples took only 6 seconds to project. This highly accelerates the movement.

The Industrial Engineer seeks to standardize on the most favorable relationship between units consumed and units produced. For best results in conducting a memomotion study we recommend the following procedure which is shown on your Memo-Card.

The procedure is generally divided into four major steps:

STEP 1: Planning for Filming

a. Inform shop personnel
b. Plan camera set-up
c. Arrange to gather supplementary data
d. Determine memomotion filming speed, period to cover, estimated total filming needs

STEP 2: Filming and Data Collection

a. Record detail of filming
b. Identify each reel by titling
c. Take film
d. Collect supplementary data

STEP 3: Analysis of Operations

a. Review film at slow projection speed (8 frames/sec.) to redetermine problem and degree of analysis
b. Define work categories and/or elemental breakdown
c. Prepare analysis sheet
d. Examine and count frame by frame recording time by category or element
e. Determine average time and, if desired, test statistically
f. Correlate supplementary data with average times

STEP 4: Presentation of Results

a. Construct standard data table and/or graphically present analysis

This visual approach will permit more rapid appraisal of the results for formulation and implementation of improvements.

Let me explain, briefly, the general content in each step:

Step 1 is "Planning for Filming."

Talk the project over with your shop people and be sure, also, that Industrial Relations knows the purpose and technique of memomotion study. Sometimes to differentiate between crew members, we ask them to wear different clothes or numbered jersey slip-overs.

Survey the job area a day or so in advance and check the camera angle, electrical outlets, and the route of a mobile study. Check the lighting to ascertain the type film, lens, and filters required. We do not use supplementary lights. Arrange to gather supplementary data such as pace rating films, secondary adjustment information, records and reports, plans and layouts.

Based on one of the three memomotion speeds, the cycle time, and objective of the study, determine the time interval to be covered. By conversion, determine the film footage required. Take a roll or two more to the job than you will need for the job.

The day before, check the operation of your motor drive and camera equipment and be sure you have enough film. Check the auxiliary equipment such as extension cord and proper plugs, tripod, dolly, and exposure meter. Also check lens, filters, title board, chalk or crayon, wrist watch or clock, and note paper. A portable wire or tape recorder often facilitates note taking. Secure an explosion meter when required.

Step 2 is "Filming and Data Collection."

Record on a Film Study Data Sheet the detail of the filming operation. This sheet is keyed into the film. It is very complete and includes a work place and camera set-up sketch. This sheet also aids in determining why film results may be faulty.

Prior to filming at memomotion speed, a few feet is run off at regular speed. At this time we usually place a title board in front of the lens showing plant, location, department, operation, date, time, and filmed by. This same data is lettered on the box to identify the film further.

Step 3 is "Analysis."

Depending on the jobs studied and the objective, the analysis can physically be recorded on paper in any one of a number of ways; in general, however, the film is usually reviewed at a slow projection speed, say 8 frames per second, to redetermine the problems and the degree of analysis. Any non-productive movement becomes quite evident during this period. You look for work assignments of individuals and their interrelationships. Then you determine and define categories of work. Another quick look at the film to reaffirm these categories, and you are ready for detailed analysis after preparing the analysis sheet.

The film is examined frame by frame, recording the time for each category. The categories are totaled and presented in some graphic manner.

Sometimes the data is tested statistically to record and indicate its reliability.

Oftentimes a rating factor is applied, but not always. We use an objective rating system developed by Dr. Mundel and subsequently improved upon by many people. It is composed of a multi-image film for pace comparison, supplemented by tabulated secondary adjustment for job difficulty.

Step 4 is "Presentation of Results."

The manner of execution of this step also varies, depending on the study objective. We try to present a simple, graphic picture that can easily be explained as portraying the activity studied.

EXAMPLES

Let's run through some examples. We have literally hundreds of rolls of this type of film, and it is difficult to know what to present. We have chosen examples showing a multi-man and machine, a man and multi-machine, multi-man and multi-machine, process breakdown, and random sampling with timer. Dr. Mundel has a 20 minute film showing other examples, and if any of you wish other examples please write me and I'll put you in touch with others who have films showing different applications of this technique.

Our first example is a multi-man and machine problem—9 men and one machine. We were asked to determine if the output could be improved. The stated purpose of the study was to analyze the rolling operation to determine the percentage of time spent on each phase of the operation. It was felt that the study of the job would lead to improved methods—the exact nature of which was not preconceived.

We had limited Industrial Engineering personnel. If we took a conventional motion study and analyzed the work with a stop watch or clock, we would take 10 studies and obviously the last study would have no relationship to the first. It was decided to run a memomotion study over a 16 hour period.

We determined the camera angles, etc., set the camera up and ran it continuously for 16 hours, changing film every hour. This gave us 16 rolls of memo film plus some pace film. We are about 150 feet from the machine. We have about a 200 foot camera angle. We needed no lighting between 7:00 a.m. and 11:00 p.m.

The film was reviewed to determine the degree to which the problem should be analyzed. We ran through the film quickly at 8 frames per second. The preliminary analysis showed that a greater portion of savings could be realized by analyzing the relation of the crew in total to the mill, rather than the individual relationship of the nine-man crew to each other and the mill.

Since I plan to demonstrate the analysis technique on the next example, let me just summarize our findings from example 1:

The analysis showed that of the 86% of available rolling time, 35% was waiting for material to heat to rolling temperature. It was estimated that the employee's efficiency could have been increased by approximately 5 to 10% through job standardization. In other words: Without having to go through the tedious task of studying each man and a machine for 16 hours, we were able to determine where a 35% increase in production was possible. The management proceeded to correct the waiting period. One of the corrective actions was to reduce the size of load and increase the frequency of load returning to the preheat furnace.

Let me point out the advantages of this type of study. If we were to analyze each man, we would only need to run through the film 9 times plus one for the machine. However, our preliminary review indicated this would be wasting our time, and we should go after the dollar savings, not pennies.

The memomotion study took 16 hours. A stop watch study would have taken 160 hours. The memomotion analysis took 40 hours. We estimated a conventional study analysis would consume 160 hours. We have a total of 56 hours vs. 320. This is the equivalent to adding between two and three men. The Industrial Engineering manpower saving paid for the equipment.

Another example of reduction in analysis time was the original study for fork truck standard performance time by John Cross at Purdue under Professor Richardson. The complete analysis took only 100 man hours vs. 1200 if done conventionally.

Our presentation in this first example included a sketch of the work area, a flow diagram, and group activity sheet. The film was also shown to the persons concerned.

The second example involves a man and multi-machine problem. The purpose of the study was to analyze this man's task, determine the percentage of time for various work categories, and determine manpower requirements. It was felt that the study would lead to the development of methods improvements.

We chose the memomotion technique because

(1) of a long cycle operation (every two hours),

(2) the job had irregular occurrences at indeterminate times in a normal cycle, and

(3) we wanted a recorded picture history, to enable everyone concerned with the activity (hourly, technical, supervision and management) to make method improvement suggestions.

Again a 16 hour study was made with check or pace film taken once an hour. The film was reviewed to establish the categories of work and the degree of analysis. Twelve categories were established and the film analyzed.

The task is performed over an area of 140′ x 100′ on two levels. This necessitated following the operator with the camera mounted on wheels. The major portion of the job involves reading, recording devices, performing periodic checks, adjusting equipment to maintain quality and quantity requirements, and maintaining good housekeeping and safety.

The analysis technique may be best illustrated by showing a few frames on the projector. With the counter set at zero starting with the category of "Read and Record" we run the projector to the end of the activity and note that the counter reads 325. The man now rests. We run the projector until this action stops and note that the counter reads 600. By successive subtraction, the elemental time data can be secured. The data is added up and converted to a percentage of the total. As can be seen, the data take off is done in the same way as a micromotion study. In this case we did not rate.

We presented the results graphically as part of a report.

Equipment has been relocated, and various additional pieces of equipment purchased, resulting in the elimination of unnecessary walking (about 60 minutes of walking eliminated). We reduced movements from the higher classification of 5th and 4th degrees to those of 3rd, 2nd, and 1st degrees and eye movements. This resulted in a 28% reduction in the man's scheduled time for the task. The investment for improvement was realized in less than eight months.

In our opinion, the simplification of the job through improvements resulted from many people's efforts. One of the biggest plus values of the film in this case is that everyone concerned would see the operation and make suggestions for improvement. The review of the 16 hours of activity took 2 hours, which included time of film stoppage for discussion purposes.

Recapping the time for this study:

Filming 16 hours

Analysis 30 hours (11 categories plus walking. The film was run through 4 times.)

Presentation 4 hours (Includes graph and personnel review.)

An example of using memomotion to analyze a multi-man and multi-machine operation is the following chemical plant packaging study. Plastic pellets were being packaged in 300 cubic foot collapsible rubber containers. These containers weigh about 500 pounds empty and 10,000 pounds loaded.

At the start of the cycle, the lift truck would pick up an empty bag in the storage area across the road and take it to a position alongside the filling cradles. There the bag was inspected and inflated. When a cradle was free, the inflated bag would be picked up with an overhead hoist, placed in the cradle and filled. The lift truck removed full bags and took them to a scale for weighing. From the scale, the bags would either go to a waiting gondola car or to temporary storage across the road.

To analyze this operation, we set up our camera in the position indicated to cover the entire area and shot 400 feet of film. At memomotion speed, this covered 4 hours of action whereas at normal speed the same amount of film would have spanned only ¼ hour. And the time lost while changing film was negligible with memomotion. Also, while taking the film we were able to leave the camera unattended and inspect the job at close range and discuss the job with the operators. Needless to say, this whole project was done with the full knowledge and cooperation of the operating people involved.

Our 4 hour film gave us a very good overall picture of the operation. However, we were only able to infer some of the activities of the 2 men assigned to the upper level of the filling cradles. They were up in a dark corner and it was a little difficult to see what they were doing. So we merely took a supplementary film of these 2 men to round out the picture.

The films which we made gave us a good clear picture of the interrelationships between 4 men and 3 major pieces of equipment. After suitable analysis, we made some minor equipment changes to reduce the attention required by the operators and rebalanced the crew. Our "after" procedure required only 3 men for the same level of output, a 25% improvement which more than justified the effort expended. Although a different analysis technique might have been used in this case, the camera was clearly the most practical tool since it was the only tool which showed the relationships among the various men and machines involved.

This particular job was done outdoors and brought forth 2 interesting problems caused by the weather which you might not think about. The film was taken on a clear but windy day and even with slow film and a red filter some slight over-exposure occurred. The other villain of the piece was the wind which introduced a slight wiggle in the camera, heavy as it was. Although these 2 problems cropped up, neither of them had an adverse effect on the analysis of the films. To me, this is a pretty good endorsement for the simplicity with which movies can be made.

Another time saving example of the memomotion technique is in the study of a production or process breakdown due to failure of some of the equipment. We wanted to study the activity at an automatic bagging machine whenever a breakdown or jam occurred. Having a man stand by waiting for a breakdown would have required entirely too much time. Since the first thing that occurred during a jam was to turn off the power, we wired the camera so that it would operate as soon as the power to the bagging machine was turned off. A similar application is possible any time your problem area can be characterized by an "on-off" or "yes-no" situation.

Several years ago, Mr. H. R. Thompson of our Texas City Chemicals plant pioneered an interesting application of memomotion to accomplish work sampling. When the idea first came up, existing films were sampled to make sure this technique would be accurate. The error introduced by sampling these films was well within the statistical variation expected when doing any work sampling, so the idea looked good.

To actuate the camera, a program timer was purchased which would start the motor at selected 5 minute intervals. This was randomized by adding hand made cams which can be changed at will. The technique as finally developed consists of taking 6 to 8 frames at random intervals at memomotion speed. Experience has shown that the 6 to 8 frames are necessary to fully recognize the activity going on. This method of work sampling has proven quite successful when the camera can be set up at a suitable vantage point and has proven to be a real time saver. A single roll of film will hold about 500 observations, so the camera can be left unattended for a full week or more while it makes an entire work sampling survey.

EQUIPMENT

We have photographs of most of the equipment necessary to make a memomotion study. I have a sheet to pass out and I'll give a few hints on the better equipment as I go along.

The equipment required includes:

- Camera (16 mm.) with lens and filters
- Motor drive
- Projector (16 mm.)
- Tripod
- Exposure meter
- Screen
- Splicer and rewinder with frame counter
- Extra cords
- Proper outlet plugs
- Dolly
- Suitable carrying equipment
- Title boards
- Chalk or crayon and eraser
- Clock (for recording time of day) with minute and hour hands
- Note paper
- Film (16 mm.)

We have reviewed today, a technique whose application is limited only by the personnel using it.

We discussed the following aspects of memomotion study:

1. What memomotion study is
2. Why the technique is employed
3. Areas that lend themselves to the technique
4. Procedure for making a study
5. Suggested equipment

In review, memomotion is a motion picture technique for analyzing the main movement in an operation to improve methods, define problem areas, or set standards and can be considered a special form of micromotion study in which the motion pictures are taken at unusually slow speeds.

Again let me say that memomotion study is a proved Industrial Engineering analysis tool. Through its use, factual data can be effectively and economically recorded and collected for analysis to assist in developing more economical methods, defining problem areas, or developing more effective measurements of performance.

It has been a pleasure to be able to discuss some of our work with you today. Thank you.

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section 4

THE NEED FOR INDUSTRIAL ENGINEERING TECHNIQUES IN PRODUCT ENGINEERING

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In 1947, he started teaching at Penn. State in the Department of Industrial Engineering. The same year he became a Professional Engineer, and consultant. In 1949, he received his M.S.I.E. degree from Penn. State and in 1955 became head of its Industrial Engineering Department.

Professor Niebel is the author of four books — *Designing for Production* (co-authored with E. N. Baldwin), *Motion & Time Study*, *Motion & Time Study Laboratory Manual*, and *Time Study* (written for International Correspondence Schools) as well as numerous magazine articles.

THE NEED FOR INDUSTRIAL ENGINEERING TECHNIQUES IN PRODUCT DEVELOPMENT

by BENJAMIN W. NIEBEL

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ACCORDING to studies made by the National Industrial Conference Board, the chances of failure of a new product are much greater than the chances of success. Whether the company involved is small or large, whether the product is of soft or hard goods, or whether the company manufactures consumer goods or industrial products, the fact is that for every five consumer products placed on the market, only one is successful.

It should be pointed out that these figures are based upon products that are put on the market. How much worse the odds would be if they included all the products that are discarded after various stages of design and development is anybody's guess.

Many progressive companies, well aware of the chances of mortality of new products, have made thorough studies as to what the symptoms and causes of failure are. If these are clearly understood and if new designs are developed to avoid these pitfalls, then product success can be contemplated with reasonable assurance. A method known as Product Planning was pioneered by the General Electric Company and has been followed by many of our country's leading industries. The Burroughs Company refers to product planning as the "key to survival." Product planning is, for the most part, the utilization of Industrial Engineering techniques in product development.

A need for a new product may become apparent in several ways. Frequently, requests coming from the field to help solve specific problems lead to the development of new apparatus. Sometimes competitors open a new field with new apparatus and a company must bring out something new in order to maintain the company's position. Occasionally, a phenomenon discovered by research workers, engineers, or other employees will lead to the development of a new product or an entire line of products.

Once the need for a product becomes evident, management must weigh the desirability of embarking on the new design.

Even though there is a need for a new product, in order to be accepted it must have the features that the potential customer wants. These include:

1. Sound functional design.
2. Eye appeal with consideration of human dimensions.
3. Quality characteristics both in material and workmanship.
4. Convenient maintenance.
5. Competitive in price.
6. Delivered to the customer in time to meet his needs.

Of the four out of five new products that end up in failures, seldom is the cause of failure poor functional design. Sound functional design assures that the product will satisfactorily operate for a reasonable period of time in the manner intended. Without sound functional design, the product would not get on the market. Investigation of the lack of success of products indicates that usually the cause of failure is due to some of the other criteria mentioned necessary for product success.

THE PRODUCT MUST HAVE EYE APPEAL AND CONSIDER HUMAN DIMENSIONS

The Industrial Engineer who continually works with people and understands their behavior patterns, recognizes the importance of appearance and utilization of human dimensions in product design. Appearance has become a major factor in all types of household appliances, machinery, process equipment, power equipment, etc. The appearance of a product makes a deep impression on a buyer: it may suggest power and speed in a locomotive, durability in a machine tool, cleanliness in hospital equipment, precision in an instrument.

The importance of appearance to the auto industry is well illustrated by the fact that the original Chrysler Air-Flow and the Buick bulging-body designs failed to attract the public. When two products have approximately the same functions, the same cost, and the same time required for delivery, the product with the better appearance will have the most sales appeal. For example, there is a length-width ratio that tends to create eye appeal. When economically possible, this ratio should be incorporated in overall and component designs so as to help assure success of the design. This proportion was originally developed by the Greek philosopher and mathematician Pythagoras and states that the length of a rectangle should be equal to one-half the width plus the square root of the sum of the width squared and one-half the width squared. Graphically, this proportion is determined as shown in Figure 1. This ratio of width to length is 1:1.62. Such style conscious concerns as General Motors and Hamilton Watch have long incorporated this "golden rectangle" relationship in many of their designs. The blending of rhythm, interest, and emphasis are other factors that help assure sales success and should be considered in the location of bosses, dials, controls, recesses, etc. while the product is being designed.

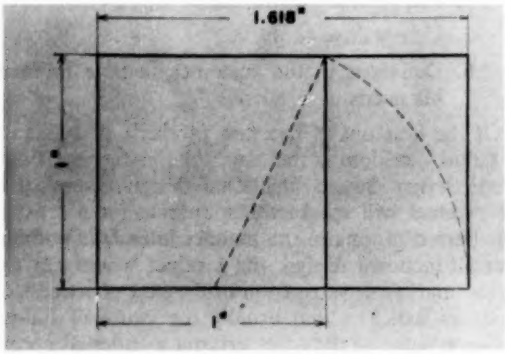

Figure 1.

Development of golden rectangle.

The much practiced Industrial Engineering technique of keeping the "human" in mind is needed when the product is designed. Consideration should be given to such factors as arm reach, leg clearance, and body support as these human dimensions are important criteria in developing worker environment that is comfortable and efficient. Many existing designs today are mechanically perfect, yet are incapable of effective operation because the designer of the facility overlooked the various human factors in the operation of the equipment. Handwheels, cranks, and levers should be of such size and placed in such positions that operator manipulation can be done with greatest proficiency and with a minimum of fatigue. Detailed Industrial Engineering studies have determined that for a given control location there is a definite point at which the size of the control and operator performance is optimum. Likewise, tests of legibility have shown certain colors when used together provide the sharpest contrast. The ten color combinations that give the greatest contrast are black on yellow, green on white, red on white, blue on white, white on blue, black on white, yellow on black, white on red, white on green, and white on black. There is a marked difference between these various combinations. For example, Figure 2 shows the relation between stroke-width of numerals and the distances at which they can be read for two contrast relations. These relationships may not be realized by the typical functional designer.

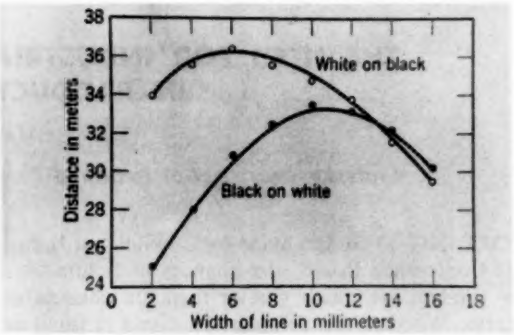

Figure 2.

Relation between stroke width of numerals and distance which they can be read.

Packaging of the product, frequently is one of the most important criteria leading to its sale. Here again the I. E. can make a significant contribution. Not only is he able to help determine the package design that best protects and displays the product, but he is able to specify the method of packaging that is most economical.

THE PRODUCT MUST HAVE QUALITY CHARACTERISTICS BOTH IN MATERIAL AND WORKMANSHIP

More than anyone else, the Industrial Engineer recognizes that quality cannot be inspected into a product, but must be designed and built into a product. Tolerances, surface finish, material specifications, and performance requirements must be specified so as to assure a product that is of adequate quality. Tolerances and specifications that are more rigid than necessary should not be assigned. There is a tendency for product designers to establish tolerances and specifications that make the cost of manufacture prohibitive. *The roughest acceptable* finish should be contemplated and so specified.

Figure 3 illustrates the relative cost of machine parts with different tolerance requirements.

Fine surface finish and close tolerances are not obtained with operations where metal removal is extremely heavy. Figure 4 indicates commercial tolerances maintained in typical machine tool operation. There is also a relationship between surface roughness and dimensional accuracy. For example, to specify a tolerance of .0002 inch on a turned diameter held to an average roughness of 500 microinches would be foolish. Similarly, a specification of 10 microinches for a surface which is intended to provide proper size for locating subsequent operations is needless. Figure 5 shows roughness figures for the common production operations.

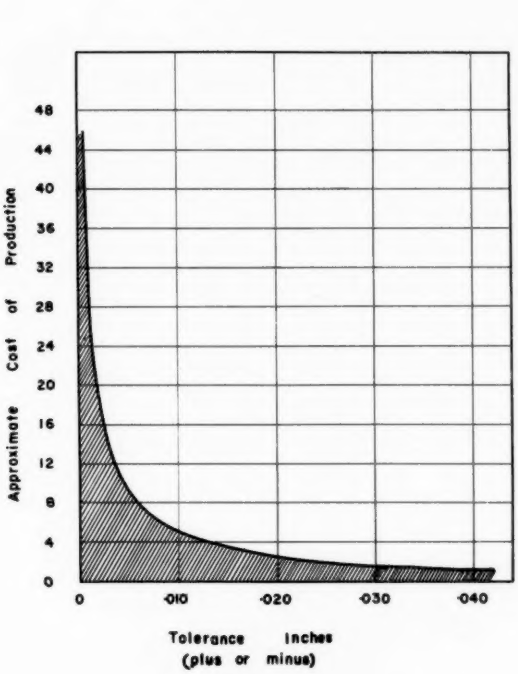

Figure 3.

Relationship of cost of production to tolerance requirements.

COMMERCIAL TOLERANCES MAINTAINED IN MACHINE TOOL OPERATION

Operation	Machine Tool	Tolerance
Rough Turning & Boring	Engine Lathe	0.005 on diam. 0.250 to 0.500
Finish Turning & Boring	Engine Lathe	0.002 on diam. 0.250 to 0.500
Threading	Engine Lathe	0.003 on major & minor diameters 0.002 on pitch diameter
Turning	Turret Lathe	0.002 on diam. & shoulder lengths
Boring	Turret Lathe	0.001 to 0.003
Threading	Automatic Opening Die	Class 3 fit
Turning & Boring	Vertical Turret Lathe	0.001 to 0.003
Turning	Automatic Lathe	0.002 to 0.005 on diam. & shoulder lengths
Turning	Automatic Screw	0.002 on diam. & shoulder lengths
Hollow Milling	Automatic Screw	0.006 to 0.010 (for roughing only)
Forming	Automatic Screw	0.003 with tool less than 3/4 wide
Drilling	Automatic Screw	0.004 with 1/4 to 1/2 drill
Reaming	Automatic Screw	0.0010 up to 1/2 reamer
Diamond Turning & Boring	Precision Boring	0.0005 to 0.0010 for steel 0.0001 to 0.0002 for non-ferrous metals
Drilling with Suitable Jigs	Drilling Machine	0.001 to 0.002 on center distances
Drilling with Suitable Jigs	Drilling Machine	0.007 with 1/4 to 1/2 drill
Drilling & Reaming	Drilling Machine	0.0010 up to 1/2 diameter
Plain Milling	Milling Machine	0.001 to 0.002 for flatness & dimension
Thread Milling	Milling Machine	0.001 to 0.002 on major & minor diam. of fine work 0.002 on pitch diameter of fine work
Profiling	Milling Machine	0.004 to 0.008 with hand feed on simple contours
Broaching	Broaching Machine	0.003
Plain Grinding	Plain Grinder	0.0005
Surface Grinding	Surface Grinder	0.0005
Face Grinding	Face Grinder	0.0020
Gage Grinding	Tool Grinder	0.00025
Honing	Honing Machine	0.0003
Planing	Shaper	0.003 to 0.005 on small to medium work
Planing	Planer	0.005 to 0.010 on medium to large work

Figure 4.

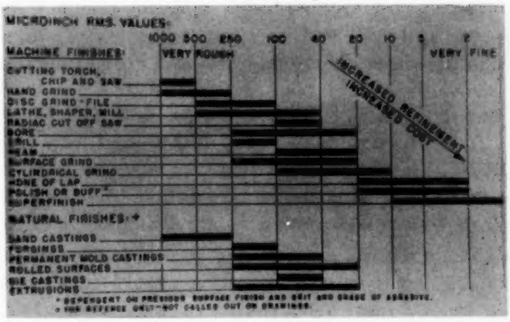

Figure 5.

Microinch values for machine finishes.

The Industrial Engineer trained in quality control techniques is able to assist in the determination of product specifications that can be most economically achieved and still maintain product quality. For example, the fact that tolerances are not additive is recognized by every quality control engineer; yet a great number of our functional designers, not familiar with laws of probability, do not take this into consideration and make component dimensions unnecessarily close in order to hold tolerances on overall dimensions. For example, the functional design of a product may necessitate the tolerances shown in Figure 6. The uninformed function designer may indicate the specifications shown in Figure 7 in order to hold the overall tolerance of .007.

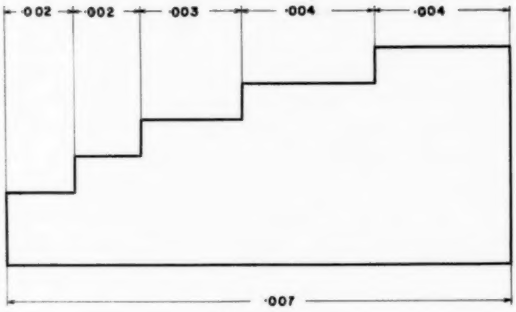

Figure 6.

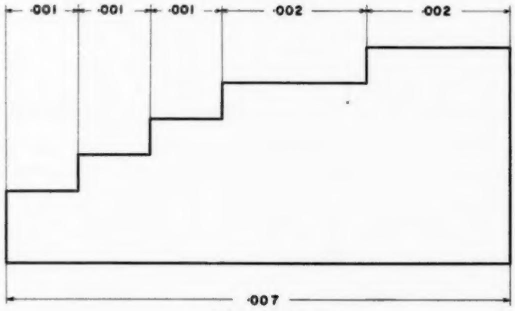

Figure 7.

The cost of holding these tolerances would obviously be large. However, since the overall tolerances can be safely dimensioned with a tolerance equal to the square root of the sum of the squares of the individual tolerances, the tolerances as shown on Figure 6 may be released to the shop with confidence that the overall tolerance of .007 will be maintained as long as the individual tolerances of .002, .002, .003, .004 and .004 are held.

The engineer planning the manufacture of the product, the Industrial Engineer, should collaborate with the engineer responsible for functional design in the design of a product so that there is a balance between satisfactory quality and competitive cost of production.

THE PRODUCT SHOULD BE DESIGNED FOR CONVENIENT MAINTENANCE

Practically every product produced requires periodic maintenance in order to assure satisfactory performance. Wherever moving parts are involved, lubrication must be provided or else wear will be excessive. In any event, moving parts do wear and will require replacement. Of course, stationary parts need maintenance and replacement also, especially when subjected to corrosion, load, heat, and other factors that shorten service life. In order for a design to be completely acceptable, it must be not only functionally sound, economically priced, and have sales appeal, but it also should facilitate normal maintenance and repair.

Oil cups, grease points, fan and drive belts should be readily accessible. In the design of any assembly, the ease of replacement of the various components should be directly proportional to the service life. Thus, a bearing that has a normal service life of one year on an assembly that should provide fifteen years of operating performance should be so located that it can readily be replaced.

The Industrial Engineer who has been trained in the economy of preventative maintenance, cost of machine down time, and development of indirect labor standards is extremely conscious of the desirability of ease of maintenance in all designs. He logically looks for and thinks in terms of service life. He will insist that ease of maintenance be incorporated in all new designs.

THE DESIGN MUST BE COMPETITIVE IN PRICE

Usually, final decisions are based on cost. No matter how perfect the final design may be, no matter how much eye appeal it has, it will not sell unless the price is in line with competitive products.

Selecting the manufacturing processes and recommending specific materials to be incorporated in the design should be done in conjunction with the work of the functional engineer. A person cannot do a good job of designing a product unless he knows how the product can be made. Unfortunately, too many of our functional designers do not have the manufacturing background to keep the shop in mind as the product is designed. Designs that are economical must consider the process of manufacture as well as the function of the product. With new materials continually being developed and new processes offering economies over old, it is difficult, if not impossible, for the functional designer to stay abreast of his own field and the work of the process engineer. The process or manufacturing engineer must collaborate with the functional design engineer as the product is being developed so that when the design is completed it will not only be functionally sound, but will be engineered for production thus assuring a competitive price to the consumer.

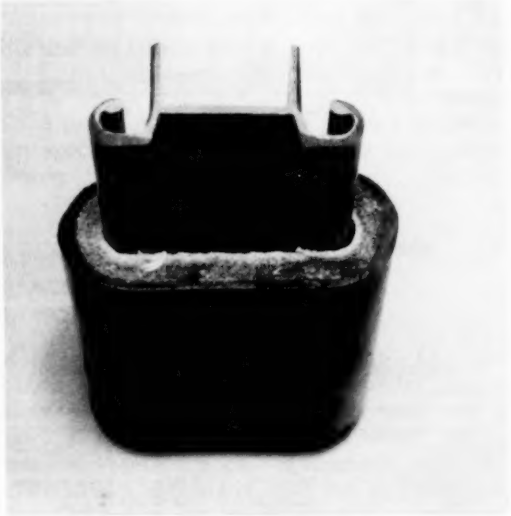

Figure 8.

Stairway rail with extruded brass insert.

Let us look at some examples: Figure 8 illustrates a piece of electric stairway rail. The insert was made of extruded brass. A non-corrosive metal was specified in view of the sulphur used in the vulcanization of the rubber rail. The functional designer indicated the section as shown which limited the process to extrusion. Thousands of feet of this type rail were produced at a cost of $1.05 per foot. In time a method study was conducted by the Industrial Engineering Department. The engineer brought out that the insert could be made of steel by coating the stock with a zinc chromate primer which would make it adequately resistant to corrosion. It was also suggested that roll forming would be more economical than hydraulic extrusion. The resulting design permitting roll forming is shown in

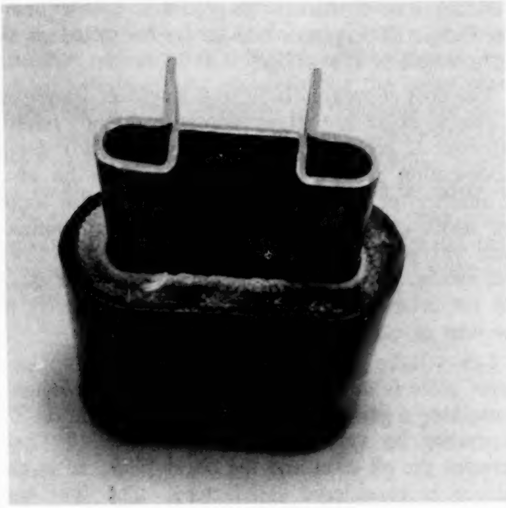

Figure 9.

Stairway rail with roll formed steel insert.

Figure 9 which was produced at a cost of $.21 per foot. Although this savings of $.84 per foot is significant, it must be remembered that thousands of feet of this rail were produced at the higher cost because Industrial Engineering was not brought into the picture while the design was being created.

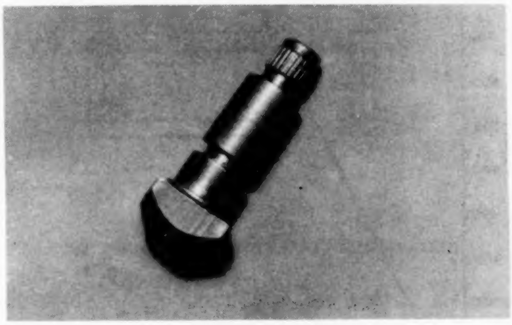

Figure 10.

Switch component made of automatic screw machine parts.

Here is another example: The switch shown in Figure 10 was made of two components, a brass nut and a cold rolled steel stud. Both components were made as automatic screw machine parts. Factory costs were $81.70 per thousand. Once again, Industrial Engineering was asked to make a method study after many parts were produced to the design shown. A molded nylon nut was substituted for the brass nut. The steel stud design was modified in size. Also, both the external threads on one end and the knurl on the other end were specified to encompass only a portion of the periphery making it possible to mold the part. Thus, the mold could be parted at the section where threads and knurl were not specified. The result was a zinc base die casting. These changes resulted in a switch of equal or better quality at a cost of only $24.16 per thousand (Figure 11).

Figure 11.

Switch component made of molded nylon nut and die cast stud.

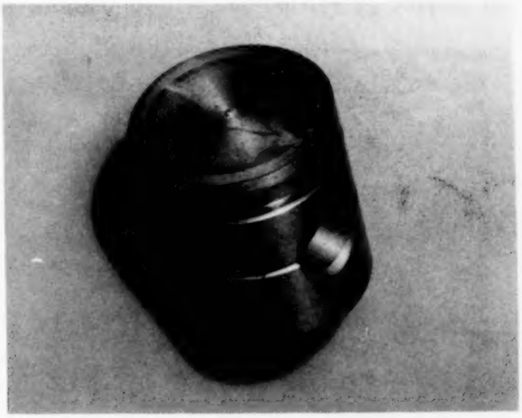

Figure 12.

Die cast piston.

Here is a die cast piston (Figure 12). Secondary operations include both turning and facing in order to meet the close tolerance and finish requirements. The functional designer was aware of the processes to be used, but was not sure how the part would be held during the machining operations. Industrial Engineering was brought in to assist with the design which resulted in a casting with holding fins as shown in Figure 13. This permitted holding the casting securely for all secondary operations without marring the finish. A final facing cut freed the finish machined casting from the fins.

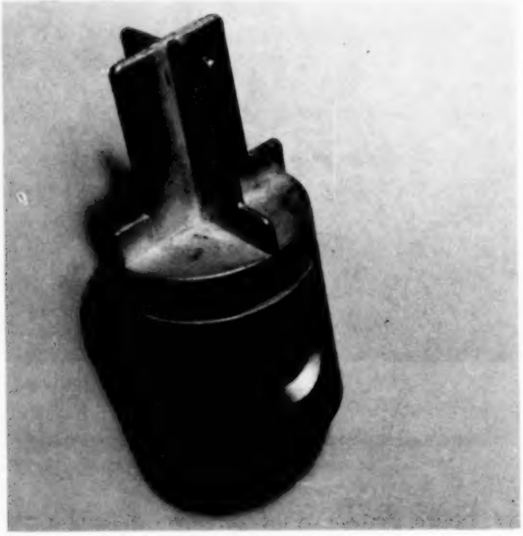

Figure 13.

Die cast piston with fin for holding.

The inclusion of drill prints, locating pads, locating holes, etc. in the design of a product, frequently will simplify its manufacture. These must be included before the tooling is planned. Consequently the Industrial Engineer should be consulted in the early stages of the design.

The cost conscious Industrial Engineer frequently is able to make important recommendations relative to material economy. Many times a minor design modification permits making a part from the scrap of another, or permits making a part from a standard width or gage. Figure 14 shows a lamination that was produced from the insert of a different lamination. The two parts which had similar quantity requirements were produced simultaneously for the cost of one.

Let us take a look at a theoretical example. A cover plate is designed to be attached to a housing containing a gear train partially immersed in oil and depending on splash lubrication. Since 12″ exist between the oil level and the cover plate, an as-cast surface is considered satisfactory. The functional designer presents the following design to the manufacturing engineer who estimates the production and tooling cost (Figure 15). The tool costs are based on a single loose wood pattern and the production operations include drilling, burring, and painting.

The manufacturing engineer may consider the following possibilities on this relatively simple design. He sees an opportunity for standardization,

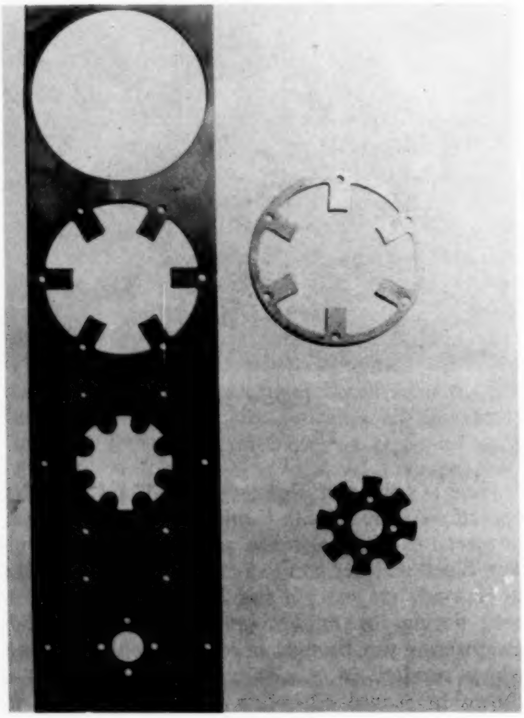

Figure 14.

Two parts are made simultaneously from this strip.

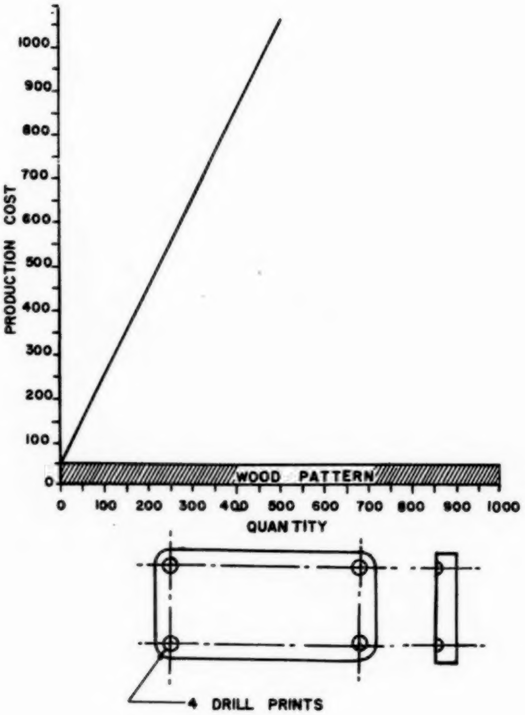

Figure 15.

Cover plate made from single wood pattern.

if this cover can be oil tight. A similar design has less distance between the oil level and the cover plate thus necessitating a better seal in order to prevent oil splashing. By standardizing the cover plate on the two designs, quantity requirements are doubled. However, it will be necessary to add a gasket to the design and introduce a rough grinding operation on the cover face. These costs can be offset by redesigning the casting to save weight and using more advanced tooling. Figure 16 shows the proposed design and the production cost by having the part made using two metal patterns on a gate. Further study brings out that if the volume were increased slightly, it would be economical to change the design from a casting to a stamping. This would eliminate both the drilling and rough grinding operations; however, the initial tooling would be much more costly as shown in Figure 17.

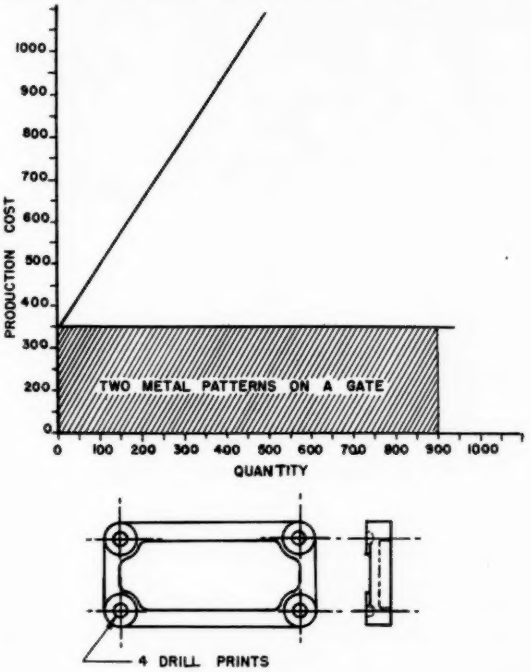

Figure 16.

Cover plate made using two metal patterns.

Perhaps, the manufacturing engineer will bring out that quality of the apparatus demands better appearance. Aluminum is suggested to give more eye appeal. This step would eliminate the need for painting. In order to bring unit costs down, the design is modified so as to incorporate thinner sections. Six patterns on a match plate is proposed, and a drill jig utilizing a multiple spindle head is planned for drilling the four hold-down bolt holes. Figure 18 shows this design and the production costs for given quantities.

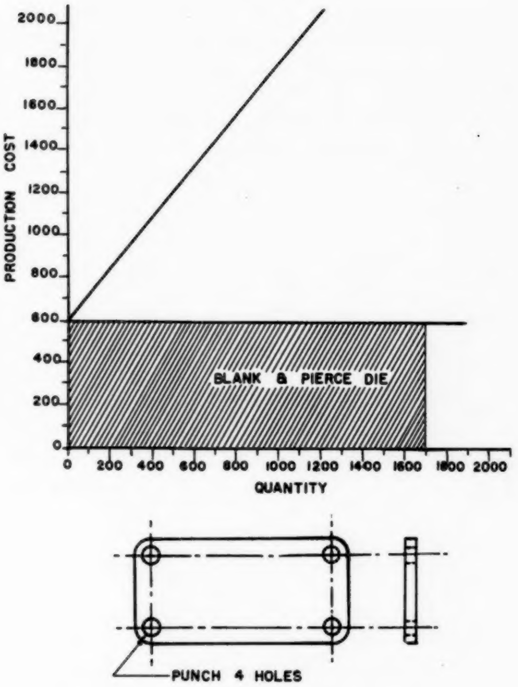

Figure 17.

Cover plate made with die.

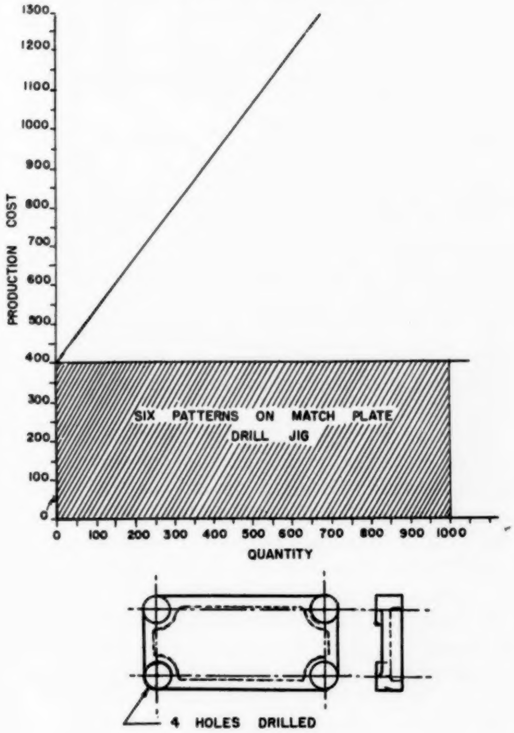

Figure 18

Cover plate made using six metal patterns.

This proposal may suggest that the cover plate be applied to other equipment which requires a better seal. Consequently, the gasket must be held in a gasket groove. A better finish and greater accuracy is necessitated through this broader standardization. This suggests producing the part in a permanent mold. This process permits casting of the four bolt holes thus eliminating the drilling operations. The closer tolerance and finish requirements can be held by the aluminum permanent mold castings. Two permanent molds are recommended and unit costs and the revised designs are shown in Figure 19.

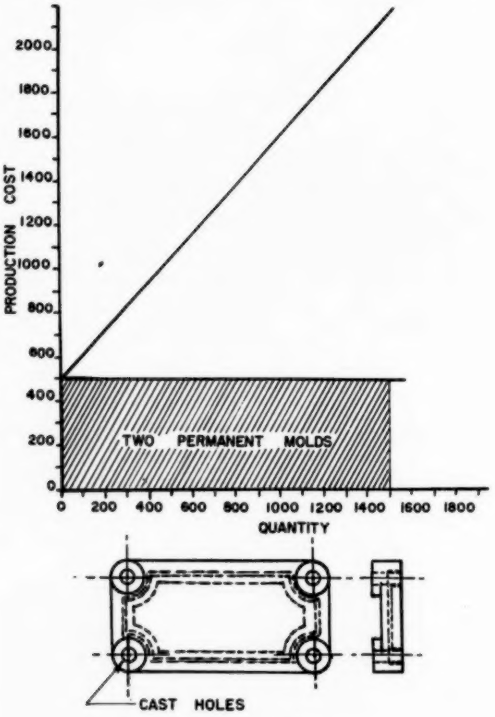

Figure 19.

Cover plate made as permanent mold casting.

Once again, appearance is considered; perhaps, activity increases or the accuracy of the part must be improved. A lacquer finish may be suggested to harmonize with the equipment. An insignia on the cover and countersinking the heads of screws is considered. These requirements suggest die casting the cover. In order to compensate for the added cost brought about by the more exacting design requirements, a zinc die casting alloy is substituted for aluminum and less material is required by die casting the part. Greater accuracy is achieved. The die cast part requires no finish operations, other than cleaning and application of the lacquer finish since the surface is better than permanent molded parts. Figure 20 illustrates this proposed design and the resulting production costs utilizing one die casting mold.

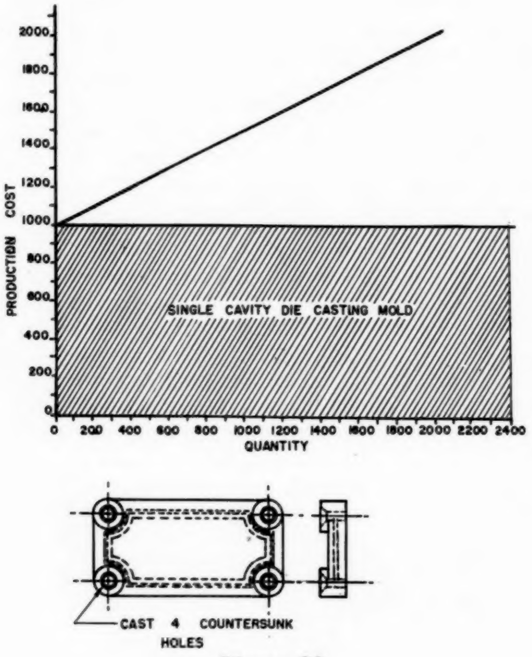

Figure 20.

Cover plate made as die casting.

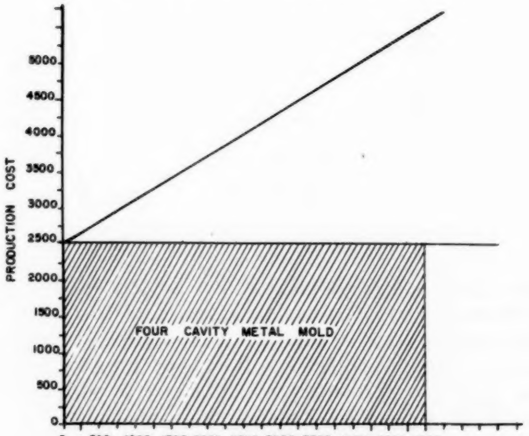

Figure 21.

Cover plate made as plastic molding.

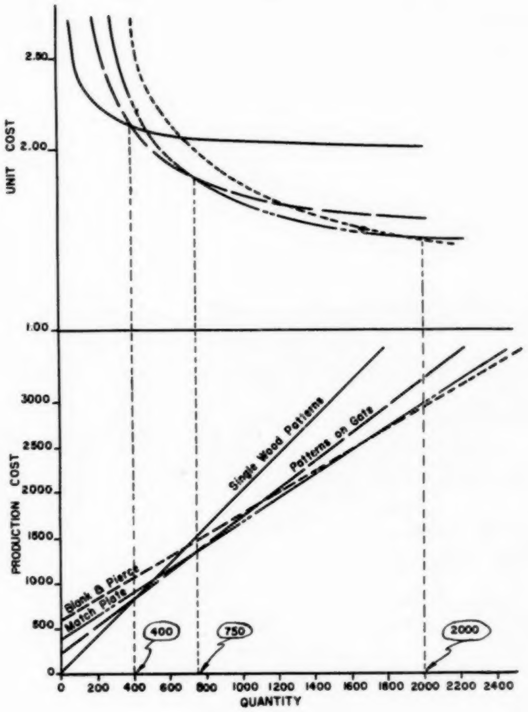

Figure 22.

Break-even points of various methods of producing cover plate.

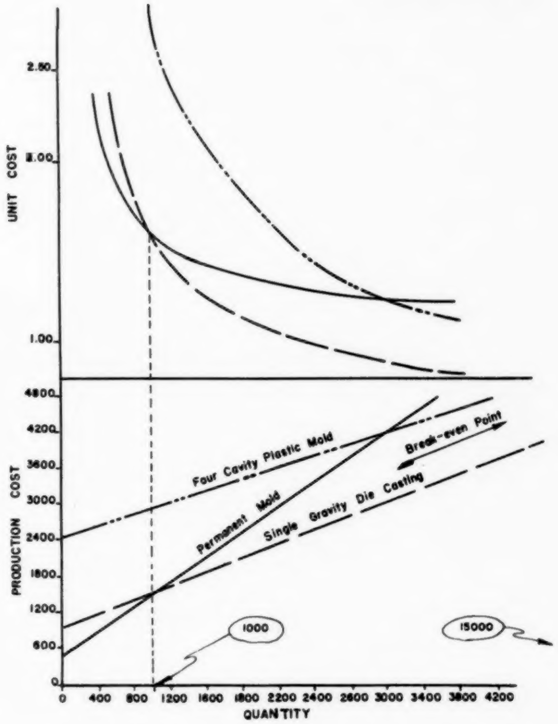

Figure 23.

Break-even points of permanent mold, die casting mold, & plastic mold.

Further study may suggest a transparent cover plate. This will reveal the level of oil, eliminate an oil gage, and permit inspection of position of parts within the housing. Therefore, a transparent plastic of a color that will harmonize with the equipment is chosen. The cost of material is increased and the slower operation of the process is offset by using a 4-cavity injection mold. Figure 21 illustrates this design and its cost of production.

In this simple part, there is a best way for producing it depending on given conditions and quantity requirements. In one production area, casting looses to rolled steel. In another, metal parts loose out to plastics and so on. Figure 22 shows the break even points of single wood patterns and two patterns on a gate (400); of two patterns on a gate and 6 patterns on a match plate (750) and six patterns on a match plate and blank and pierce die. Unit costs of production for different quantities under the four methods are shown.

Figure 23 illustrates the break even point of the two permanent molds and the single cavity die casting mold (1000) and the four cavity plastic mold and the die casting mold (15,000).

This example brings out the desirability of making engineering economy studies to determine the most favorable design and tooling for given quantity requirements.

In our present competitive economy with increasing competition from foreign manufacturers, it is emphatic that a higher percentage of designs placed on the market are financially successful. One financially successful product cannot carry four products that are financial failures. The Industrial Engineer, that is the engineer of manufacturing, can be the key to product success. The successful company today will use Industrial Engineering techniques in the design stages of new products.

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PRODUCTIVITY – KEY TO AMERICAN STANDARD OF LIVING

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Mr. Kotchian has been Vice President of the Lockheed Aircraft Corporation and General Manager of the Georgia Division at Marietta since October 1956.

Since he moved to Georgia from the Lockheed Aircraft Corporation's home office in Burbank, California in early 1951, Mr. Kotchian has found time for many outside activities, including being president of the Associated Industries of Georgia, member of the Governor of Georgia's Nuclear Advisory Commission, director of the Georgia State Chamber of Commerce, and president of the Marietta-Cobb County Y.M.C.A.

He is a director of Rich's, Inc. of Atlanta, Georgia.

Mr. Kotchian was born in 1914 in North Dakota, and was raised in Long Beach, California where he received his primary and secondary schooling. He received his A.B. degree from Stanford University in 1935, and his Master of Business Administration degree from Stanford in 1938.

Today Mr. Kotchian resides in Marietta with his wife, Lucy, and their son, Bobby. He is a member of the Marietta Presbyterian Church.

PRODUCTIVITY—KEY TO AMERICAN STANDARD OF LIVING

by A. CARL KOTCHIAN
Vice President, Lockheed Aircraft Corporation, and General Manager, Georgia Division
and
President, Associated Industries of Georgia

MR. TOASTMASTER, distinguished guests, members of the American Institute of Industrial Engineers.

You complimented me when you invited me here today to take part in your 10th Annual Conference on "Expanding Horizons of Industrial Engineering Leading to Increased Productivity." I feel also that this conference is a salute to the growing industrial development in the south. I firmly believe that in this part of the nation, we today have the No. 1 industrial opportunity. This I say as a native of North Dakota who grew up and worked for many years in California.

So as President of the Associated Industries of Georgia and as a self-appointed Chairman of the Chamber of Commerce Welcoming Committee, I bid you greetings and commend to you the wonderful natural resources abundant here to aid most any industry seeking Expanding Horizons.

* * *

Whether we know it or not, we are engaged in a battle of brains, invention and productivity. It is the Western world versus the USSR, and the Peoples Republic of the Chinese—including their supporters, both in the satellite countries and in the Western world, who knowingly or unwittingly support the Communist or Statism philosophy.

This battle in its most obvious form concerns our efforts to maintain arms superiority, or if that is not feasible, at least arms equality—not just in one field, but in the sum total of our defense effort.

We must have a hard core of highly trained, heavily armed ground troops, completely mobile on both the ground and in the air; who can contain brush fire warfare wherever it might occur throughout the borders of the Western world. We have had such instances time and again since the end of World War II—in Korea, Indo China, Lebanon, Quemoy, Formosa.

There is every reason to believe that Khrushchev and company will use their supporters in the satellite countries to continue this type of probing activity to test our mettle. We must be prepared for this.

We must have a strong Air Force providing air defense and logistic support for all phases of our defense effort.

We must have the weapons of massive retaliation to counter the direct Russian threat. These consist of SAC long-range bombers, IRBMs, ICBMs and Polaris-firing nuclear-powered submarines. These are all means of loosing on Communist soil atomic warheads, if our homeland should be violated.

We must increase our explorations into space for the weapons of the future may well develop from this field.

We must do all these things to maintain our armed truce with an adversary who time and again has shown he cannot be trusted. If we do these things we will remain so strong that nuclear destruction of both the East and the West may well never commence.

We all fervently hope a nuclear war can be averted; however, to maintain our strength we must meet or surpass our adversary in brains, invention, and productivity—not only in national defense, but in all fields of social and economic endeavor.

When Sputnik I went into orbit in October of 1957, we and the Western world suffered a grievous defeat. But maybe we had it coming. We sometimes are too cocksure. The Russians are good. They have proved it. We have a real battle across the whole gamut of our existence.

BATTLE OF BRAIN AND EDUCATION

We cannot will a plant to grow. We must analyze the soil until the best natural earth is found. We must enrich it with fertilizer. We must see that it receives water, sunlight, and insect prevention. Then and only then will the plant produce to its best products in abundance for our harvest.

Education must be the same—selective and motivated—by independent thinkers, not atomatons. We have recently heard much discussion of the relative merits of Education Systems in Europe and in the U. S. Europe has followed the intensive system in their education. This system has not paid off in Europe Our system is not necessarily no good. Education must not be a mechanical process for turning out people.

Invention. We must devote an increasing part of our national effort to pure scientific research. This is the seed corn of our future. The Russians are doing it by State decree. Our great universities and private enterprises must devote an equal amount of brains, energy, facilities, and money or we will fall behind in the battle for inventions.

But inventions are only seeds that must be nurtured into useful things for living, health, or defense by productivity.

Some may say I am too concerned with material things. There are also the battles of social conduct:

Christian religion versus Communist Atheism.

Christian morality versus Communist discipline.

Republican principles of self-government versus Communist dictatorship.

Personal liberty versus Communist planning.

However, I would like to concentrate on productivity for that's the main theme of my remarks here today.

The Communists have Industrial Engineers and good ones—well trained, industrious and dedicated. They are in direct competition with all of you to increase the productivity of the Communist system above that being achieved in the Western world of free enterprise.

We *must*—no doubt about it—find the best way to produce all products and services. The products must require the least man-hours in their production so that our available workforce may have added leisure, or the time in which to produce more goods and services.

However, the Russians and the Chinese can do the same thing. Therefore, along with techniques, we must look at motivation. A Communist is motivated by evangelistic zeal, fear of a concentration camp, leadership, national pride, and competition between men or production units under their quota system.

We must counter or surpass them in all these areas as well as in the field of operating techniques.

We must find ways to motivate our entire society. We must be convinced that it is more important and satisfying to produce a quality product or service with the least expenditure of time and effort than it is to receive a paycheck for the least expenditure of time and effort.

We must provide organization, training and communications that will lead our society to follow the star of productivity that will guarantee real security rather than the false prophet of make-work.

We must be convinced that we are in a real battle and we must win or Communism will conquer us by force of arms or force of ideas.

We must have competition between men; for if we do not, the Communist quota system will surpass us.

We must have profit competition between industrial units or the state imposed quotas in Russia and China may produce greater productivity.

I think we have the intelligence, ingenuity, training, and good sense to do those things. If we do, we can stalemate the Communists, we can avoid a nuclear holocaust, and we can provide in the future, as we have in the past, ever increasing productivity; and therefore, an ever increasing standard of living throughout America and the free world.

section 6

ORGANIZING FOR BETTER UTILIZATION OF INDUSTRIAL ENGINEERS

by **DR. RAYMOND VILLERS**
Head

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Dr. Villers, who is Associate Professor of Industrial Engineering at Stevens Institute of Technology and Lecturer in Industrial Engineering at Columbia University, has for many years been engaged in intensive research work in industrial organization, production planning, and profit control.

As an author, Dr. Villers has written the books *Economics of Industrial Management* (1949), *Budgetary Control* (1950), and the *Dynamics of Industrial Management* (1954); the chapter entitled "Industrial Budgeting" for Ireson and Grant's *Handbook of Industrial Engineering and Management* (1955); and many scientific papers and articles.

For many years Dr. Villers was a close associate of Dr. Rautenstrauch, one of the pioneers in the promotion of scientific methods in industrial management, and now heads the firm of Rautenstrauch and Villers, Consultants in Industrial Management.

ORGANIZING FOR BETTER UTILIZATION OF INDUSTRIAL ENGINEERS

by DR. RAYMOND VILLERS

Rautenstrauch and Villers, Consultants in Industrial
Management, New York City.

ALL of you are familiar with the trend toward using mathematical models to solve the complex problems of industrial production.[1] This trend is related to an increasingly better understanding of the philosophy of mathematics,[2] and it has definite merits.

Don't take me too seriously when I propose a mathematical model to solve the problem of organizing for better utilization of Industrial Engineers. Take it with a grain of salt. Yet, give some thought to it. I really think that it may help us to clarify the fundamentals of the problem. Here is the mathematical model:

$$\frac{1}{5} + \frac{1}{7} + \frac{1}{11} + \frac{1}{13} + \frac{1}{17} + X = 1$$

What does it mean? We will come back to it. First, let me briefly review another trend:

In recent years, the engineering profession has received increasing recognition. Not only a greater number of students have enrolled in engineering studies, not only the salaries offered to the engineers have increased substantially, but when you read the newspapers and the non-technical magazines, you can see that more and more recognition is given by the non-engineers to the engineering profession. It can be noted, that our profession of Industrial Engineering not only has followed this trend, but has proceeded at an even more accelerated pace.[3] Within the last decade, the number of Industrial Engineers has increased at an impressive rate. So has the prestige of the Industrial Engineer within the organization with which he is associated. At the same time, the scope and the diversification of his own activities has increased very rapidly, and it can be expected that this trend will continue in the years to come.

As recently stated by George H. Gustat, the President of our Institute, in his 1959 Message:

> "... the challenges and opportunities ahead for the Industrial Engineer are probably as great or greater today than at any other time in the history of the profession. A great amount of his ability to fulfill his challenge will depend on his knowledge to understand, evaluate, motivate and design for his fellow humans. In these respects, he will be faced with the momentous task of coordination and communications represented by many fields of endeavor ... The opportunity exists, the challenge is evident, the time is now."[4]

Most of us, I am sure, will agree with this message of our President, George H. Gustat. In fact, an increasing number of executives are aware of this trend. This is why greater attention has been given throughout industry to the study we now want to review: "Organizing for Better Utilization of Industrial Engineers."

Essentially, to meet this challenge, it is necessary to answer two fundamental questions:

First, What is the purpose to be served by the Industrial Engineer?

Second, What kind of organizational structure is best adapted to enable the Industrial Engineer to serve his purpose?

With regard to the purpose to be served by the Industrial Engineer—after a few years of uncertainty and discussions, we have now reached the point where there is a common agreement among ourselves as to how to define Industrial Engineering. In accordance with the definition adopted by the AIIE at the 1956 National Convention, "Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems."

THE FUNDAMENTAL PROBLEM OF MODERN INDUSTRY

To relate this definition to what can be called *the* fundamental problem of modern industry, let us first use a case study. Then we will use the mathematical model

$$\frac{1}{5} + \frac{1}{7} + \frac{1}{11} + \frac{1}{13} + \frac{1}{17} + X = 1$$

The case study will be an attempt to compare production by modern industry to production before modern industry existed. Very few items are available for use in such a case study. The reason is that television sets, automobiles or electronic computers were not produced in the old-fashioned machine shop. Fortunately, there is at least one item that was produced in the old time, and that is produced today with hardly any change. It is in almost, if not in all, cases the same material, the same design, the same process. I am speaking of shoes. In the old time, the workman, sitting at a low bench, fitted his own stock, sewed uppers to sole, and finished the bottoms. He often used tools which he had inherited and which were scarcely different from those used in the distant past. Some of them were actually reminiscent of those pictured on the walls of the pharaohs' tombs of ancient Egypt. They included essentially a lapstone, hammer, stirrup whiboard, pincers, nippers, shoulder stick, fender bead, scraper, and knives of different sizes. Dogfish skin was used instead of sandpaper then unknown.

The shoemaker learned his trade during an apprenticeship that lasted about seven years. He was instructed in the preparation of the insole and outsole, depending almost entirely upon his eye for the proper proportions. Pegged shoes were the most common type of footwear in the first half of the nineteenth century; the workman had been taught to prepare and drive his own pegs.

Although there were at least a few large shops in existence by the end of the eighteenth century, the general practice was that shoes were made by a shoemaker working alone for his own account or with the help of an apprentice. He would make the shoes either at his own house or at his customer's house.

This man was the tool engineer, the salesman, the purchasing agent and the president of the company. Today shoes are being made in plants employing a thousand men or women or more, working in the plants, the offices, the sales division. If you visit this plant, you will find that no one of these thousand men or women would be able to make a single pair of shoes if left alone with the leather and either the machines now used in the plants or the hand tools of the old-fashion type. Some of these people are press operators, others are packers, still others accountants or executives, maintenance engineers or designers, salesmen or budgeters—not one is a shoemaker in the true sense of the word. Yet, as a group, these thousand men and women actually produce shoes at the rate of approximately 2 million pairs a year.

Who, then, makes these shoes, if none of the group does? This question may seem rather insignificant. Actually, however, it raises the fundamental issue of modern industry and the proper answer to this question is the solution to optimum efficiency in industrial production. Modern industry makes products that no one can make. It is not because you put together a group of people who don't know how to make a product that the product can be made. It requires more than putting the people together. It requires the integration of specialized skills. This process of integration is really the essence of the previously quoted definition of Industrial Engineering. The use of a mathematical model will give us a chance to go to the roots of the problem.

As I told you, don't take too seriously my proposal to follow the trend toward more and more usage of mathematical models for the purpose of getting a better understanding of complex situations. At this time, I am only half serious. The mathematical model I am suggesting would not be acceptable to any electronic computer. But it may help us to clarify our study:

$$\frac{1}{5} + \frac{1}{7} + \frac{1}{11} + \frac{1}{13} + \frac{1}{17} + X = 1$$

Each of these fractions represent the assignment and the share of activities of each specialized function, the tool engineer, the salesman, the accountant, the purchasing agent, etc.

To reach efficiency as represented by the goal of 1, which represents unity of effort, it is necessary to cumulate all of these fractions and to add whatever is missing to reach the goal of 1.

FINDING A COMMON DEMONINATOR

To combine the activities of the tool engineer with that of the salesman and of the accountant and of all other specialists is as much a problem as to add 1/7 to 1/11. The tool engineer and the salesman, because of their extremely different backgrounds and because of their extremely different daily activities, do not speak the same language. There is a need for integrating their activities by determining a common standard in terms of timing of operation, cost of operation and planning of activities. When you add fractions, this is accomplished by finding a common denominator. In terms of integrating the specialized skills in industry, this is accomplished by proper planning; proper determination of standards of measurement. This is where the Industrial Engineer steps in.

When we return to the above mathematical model, after we have defined the common denominator, which in this case is 85085, we find that this model can be written as:

$$\frac{17017}{85085} + \frac{12155}{85085} + \frac{7735}{85085} + \frac{6545}{85085} + \frac{5005}{85085} + X = 1$$

The value of 1/5 is unchanged, because

$$\frac{1}{5} = \frac{17017}{85085}$$

The same is true for each of the other fractions: 1/7, 1/11, 1/13, 1/17; the same is true for each function within the industrial organization: tool engineering, accounting, marketing, manufacturing. Within the proper organizational structure, the activities of each function can be related to all other functions, in spite of their specializations. This can be done by the use of a common denominator which does not affect their true value and does not interfere unduly with their freedom of action.

In the case of our mathematical model, we find that such a common denominator, without changing the value of each fraction, makes it possible to add 1/5 to 1/7 to 1/11 to 1/13 to 1/17 and thus makes it possible to determine that

$$\frac{48457}{85085} + X = 1$$

This indicates that a value of

$$X = \frac{36628}{85085}$$

is needed to get 1, i.e. to reach the goal of unity. In industry this value of "x" is represented by managerial action. Regardless of the carefulness of planning, regardless of the reliability of standards, there is an absolute necessity for managerial action to take care of the unexpected, to stimulate the spirit of cooperation, to remedy failures to perform, to compensate unavoidable mistakes in planning and to make decisions based partly upon scientific planning and partly upon intuition and risk taking.[5]

This amounts to saying that scientific methods of analysis and measurement, which is the field of the Industrial Engineer, never provides a substitute for managerial ability. It is the manager's responsibility to make the decisions. But scientific methods of measurement and analysis along the line of the Industrial Engineer's profession, when fully understood and adequately utilized, provide the basis for rational decisions by management. How can the Industrial Engineering function be best organized to serve this purpose of providing management with the scientific methods of measurement and analysis that are needed by modern industry for the purpose of effectively integrating the specialized skills of all functions involved?

This brings us now to Part II of our study: What kind or organizational structure is best adapted to enable the Industrial Engineer to serve this purpose?

The answer to this question raises one of the most controversial issues of organization planning.

Modern industry has gone beyond the one-man organization. With due exception of fewer and fewer small shops, the General Managers, the Vice-Presidents, the Presidents, have few, if any, opportunities to exercise direct leadership. This raises the problem of delegation of authority and responsibility.

Decentralization is the answer. There is general agreement that decentralization must be a balance between too much "bossism" on the one side, which amounts to dictatorship and brings a high turnover of personnel and an unpleasant climate; and lack of leadership, on the other side, which amounts to abdication and creates a chaotic situation. Today this need for a balance between the two extremes is generally well recognized. Of course, you still meet unpleasant situations where the principle is violated, but, at least, the principle is well recognized.

Where the controversy starts is when it comes to decide along which lines decentralization should be effected.

TYPES OF DECENTRALIZATION

Geographical decentralization is the non-controversial line whenever you deal with a large corporation. The controversy starts when you want to decentralize further, either within the middle-sized corporation or within the already geographically decentralized division of the large corporation.

Two approaches can be followed which are fundamentally different: One type of decentralization is based upon the determination of independent profit centers; the other type is functional decentralization. In all fairness to you, I must state that I am fully prejudiced in favor of functional decentralization to which I have devoted more than 10 years of research, and which I have seen operating very successfully in industry.[6,7,8]

Decentralization by profit centers has obvious advantages. It is easier to define it clearly, it is easier to provide for the measurement of efficiency. The standard is the dollar. It is more quickly effective than any other type of decentralization. It is also much easier to operate, at least for a while. Management feels more secure, because of the obvious reliability of the standard of measurement. In the short run, it is good. In the long run, however, it often creates conflicts among the profit centers: the engineer in charge of *this* development is not interested in *that* development; the manager in charge of *this* product line is not interested in *that* product line. Their conflicting interests create a climate which some consider healthy, some consider unhealthy. Let us not spend too much time on debating what is a highly controversial issue. Permit me to concentrate on what I consider as the best approach, the functional decentralization. One thing is obvious in any case: functional decentralization is the one that requires the kind of standards of measurement that the Industrial Engineer is best qualified to provide, as can be shown if we briefly review the fundamentals of functional decentralization. Essentially, the following steps have to be taken:

Step 1—to define the functional lines of authority and responsibility.

Step 2—to provide for each function the standards of measurement of its performances.

Step 3—to record the actual performances.

Step 4—to compare the actual performance to the standard and to analyze the variance whenever warranted.

Step 5—to take managerial action if and when needed.

Step 1, to define the functional lines of authority, is essentially a problem of organizational planning. It involves more than designing the conventional organization chart. It also requires a reasonably clear and reasonably detailed description of inter-functional relationships.

Such an adequate design of the organizational structure requires an unbiased understanding of financial, technical and psychological problems: man, money, the machine. The Industrial Engineer is obviously the one whose training has given him this well balanced background and this is why there is an increasing recognition that the Industrial Engineer is well qualified to take care of Step 1 and should, therefore, be assigned, within the organization, the specific duty of designing the organizational structure and of revising it periodically to keep it up-to-date with changes in personnel and/or changes in the conditions of operations.[4,9]

Step 2 is to provide for each function an adequate standard of measurement. Even if you don't have functional decentralization, there is a need for some sort of planning which requires such standards as cost or time. But functional decentralization requires more precise standards because its ultimate purpose is to reconcile the individual freedom of action on the part of the leader of each function with the need for efficiently coordinated action of all functions. To do so, it is necessary for each function to know:

—what should be done
—when it should be done
—at what cost it can be done

The head of the function should not be expected to determine such standards on his own. The tool engineer knows how long it will take to make the tools. He does not know, however, what the manufacturing cycle is, how long it takes to purchase the material and have it delivered, how much we can afford to spend on tools, when the goods should be on the market, what other items have to be produced on the same machines at about the same time. There again we can use our mathematical model. The tool engineer knows himself as 1/7. Only someone who has evaluated the other functions as 1/5, 1/11, 1/13, 1/17 and has computed a common denominator can tell him that he is the equivalent of 12155/85085. Who is best qualified to do so?

The answer can be: management does it on the spur of the moment, intuitively. This is now generally considered an inadequate approach.

The answer can also be: let us have a committee or meetings or a product manager.

A better answer is: let us have a specialized function in charge of determining such standards in the form of detailed planning.

There is an increasing recognition in industry that planning has to be, and can be, accurate and requires a specialized function. If you apply the concept of functional decentralization, the planning function does not give orders to the other functions. It offers assignments that have to be accepted. It reports to the higher level of management whenever the decentralized function, using its best judgment, decides not to accept such an assignment, in accordance with the sound concept that it is much better for the organization to hear a "no" ahead of time and remedy the situation, rather than to hear "yes" and face a failure later on.

The planning function requires an understanding of all specialized activities; the ability to relate one to the other by determining the common denominator. Here again the field is wide open for the Industrial Engineer and in fact an increasing number of Industrial Engineers seem to have received such an assignment. The trend toward the use of electronic computers and mathematical approach in planning will, if anything, make it more and more necessary to place the planning function in the hands of someone who has a comprehensive training such as the one received by the Industrial Engineer.

It is also more and more recognized in industry that planning should include engineering research.[10] One more reason why the planning function should be assigned to the Industrial Engineer, who can understand the relationship between science, money and the customer's reaction.

Step 3—To record the actual performance does not require the services of the Industrial Engineer, but

Step 4—To compare the actual performance to the standard and to analyze the variance whenever warranted, is again a field where the Industrial Engineer can provide useful knowledge and experience.

Step 5—To take managerial action if and when needed, is not the task of the Industrial Engineer himself, but he can and should be assigned the duty of evaluating the relative worth of alternatives. Rarely, if ever, does the manager decide between good and bad. The manager decides what would be the worst (when things go bad) and what would be the best (when things go well). His decision rarely, if ever, is based upon certainty. It almost always involves risk taking.[5] But a lot can be gained by putting on his desk the quantitative analysis of the situation to the extent to which such an analysis can be made. Here again, because of his training in statistics, in mathematics, in accounting, in break-even analysis,[11] in the various techniques that some people like to call operations research, rather than Industrial Engineering,[12] the Industrial Engineer is specifically trained to provide an evaluation of the relative worth of alternatives.[13]

If we agree that the Industrial Engineer is definitely well qualified to take care of these steps, what then should be his place in the organization chart?

The answer to that question is provided by the new trends in industry:

Up to the last few years, the Industrial Engineer was more or less restricted to the plant activities. The plant activities are and definitely will remain part of his duties. Today, however, it is more and more recognized that to obtain a better utilization of the Industrial Engineer, the organization should put him in the position of establishing functional relationships with all functions.

In recent years, a growing number of companies have created a new function at top level of management. The terminology varies: some companies have a Vice-President, Operations; others have a Vice-President in charge of Consulting Services; others have a Vice-President, Administration. It can be reasonably expected that in the years to come, the staff of such a Vice-President will be heavily loaded with Industrial Engineers.

In any case, what is important is not the terminology that is being used. What is important is to recognize that to obtain a better utilization of Industrial Engineers, the organizational structure should give them the contacts they need with each and every other function. This enables the Industrial Engineer to serve his purpose of providing management with the scientific methods of measurement and analysis that are needed by modern industry, so as to effectively integrate the specialized skills of all functions involved.

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IS THERE SOMETHING BETTER THAN MONETARY INCENTIVES FOR MAXIMUM PRODUCTIVITY?

by **STEPHEN L. PALMERT**
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MR. PALMERT graduated in 1931 from New York University with a B. S. in Mechanical Engineering. He has had an extensive background in general Industrial Engineering including the installation and supervision of various types of work incentive plans.

Since his graduation but prior to becoming Chief Industrial Engineer for the Whirlpool Corporation, Mr. Palmert was employed by such firms as Westinghouse, Bendix, Air Associates, Continental Can Company, and A. C. Gilbert. His experience during this period included the installation of wage incentive plans and a production planning and scheduling system for Air Associates, Inc., the installation of a flexible budgetary control plan for Continental Can Company, and the installation of a standard hour time plan for A. C. Gilbert.

While Chief Industrial Engineer of the Whirlpool Corporation, St. Joseph Division, he brought under control a wage incentive plan that was fastly deteriorating; subsequently, the operations were converted to a fair-day work plan disregarding incentives.

Currently, Mr. Palmert is Chief Industrial Engineer for the Harley-Davidson Motor Company which is converting from a piece work plan to a standard hour plan.

IS THERE SOMETHING BETTER THAN MONETARY INCENTIVES FOR MAXIMUM PRODUCTIVITY?

by STEVEN L. PALMERT

Chief Industrial Engineer, Harley-Davidson Motor Company

WITH incentive systems, you will periodically encounter problems of selling a standard or standards, to the operators or union. These problems can be vexing and time consuming. Otherwise, good industrial relations can become temporarily strained. As a result, someone in top management may ask the question, "Is There Something Better Than Monetary Incentives For Maximum Productivity?"

There is a second circumstance that would prompt asking this question. When it is evident that the maximum productivity under the Wage Incentive Plan is not being effected. In other words, when the system is out of control. Early quitting by the operators because they have "earned their money," is a manifestation of advance stages of incentive plan deterioration.

My objective today is to compare productivity that can be expected from the various systems in use today. This comparison must consider that each plan is operating to the latent potential normally attained with it. We cannot use the exceptional aside from considering what makes it exceptional. And then question whether these features can be applied to our everyday operations to improve them.

Nor can we condemn a plan because we know of one or more plants working under this system and doing very poorly. Rather, in such instances, the reason for their failure should give us warning as to the dangers encountered when working with this plan.

What is essential to secure maximum productivity from our operators? In my opinion, they are: (1) development of the best method, (2) proper instruction to the operators what this method is, (3) good work effort, (4) elimination of controllable interferences, and (5) adequate controls that highlight whenever the foregoing factors are not at maximum efficiency.

I will review the four basic systems in use in our manufacturing plants today. Also, I will present the productivity that may be expected under each. Each of the four systems has its advantages and shortcomings. Let us look at what they are. Let us also examine whether they have the five characteristics required to secure maximum productivity.

May I clarify that when I refer to Wage Incentive Plans in this discussion, I mean measured or direct Wage Incentive Plans. I am excluding all indirect wage incentives. A profit-sharing plan is an indirect wage incentive plan. An incentive plan that pays an incentive on such a broad standard as total tons shipped, is an indirect wage incentive plan.

DEFINITION OF PLANS

There are four basic plans in use in our manufacturing plants today. They are the Day Work Plan, Measured Day Work Plan, Fair Day Work Plan, and Wage Incentive Plan.

The Day Work Plan is one in which no measurement is made as to how long a job should take. If a time keeping system is used, it may be possible to determine the time that was actually consumed to do a specific job. Frequently, even this is impossible. The operator is paid his base rate for all hours worked irrespective of productivity.

The Measured Day Work Plan, as the name implies, involves the measurement of time required for the performance of the various shop operations. It can and should include measurement of the time required to perform both productive and non-productive operations. The time required to perform a job is determined either through time study, standard data, or by use of a predetermined time system. The operator is told the standard time for each job he performs. He is expected to perform the job within or in less than the standard time. However, there is no financial incentive paid for him to meet or beat the standard. As under the Day Work Plan, the operator is paid a guaranteed base rate for all hours he works irrespective of productivity.

The Fair Day Work Plan is similar to the Measured Day Work Plan. Time standards are developed for all operations. The operator receives no financial incentive to perform the job within or less than the time standard. The main difference between these two plans is that under the Fair Day Work Plan, the operator is not told what the standard is. All discussions regarding time standards between management and employees is discouraged. Under this plan, emphasis is placed upon good supervision, good job instruction, the best methodization of the job consistent with the economics of the situation, the adherence of the operator to the prescribed method, and their putting forth a fair day effort while working from "buzzer to buzzer."

A Wage Incentive Plan pays the operator in relationship to the production that he or the group in which he works puts forth. His performance is measured against established standards. By exceeding the expected performance, his earnings exceed the guaranteed base pay, usually in direct ratio. The more common wage incentive plans are piece work, standard minute, and standard hour plans.

BASIS OF COMPARISON

When comparing the various systems, I will do so on a basis of 100 percent performance. In this case, 100 percent performance is a high task effort. The non-incentive installations that I was associated with were on this basis. If such a plan were placed on incentive, incentive payment would begin at 80 percent performance. This 80 percent performance is the same as 100 percent performance under most incentive standard hour plans where the operator expectancy is 125 percent. The 125 percent effort corresponds to the high task effort of 100 percent I will use today. In relationship to a sixty-minute hour plan with a seventy-five-minute expectancy, the 100 percent high task I am using is equivalent to a seventy-five minute hour.

WORK MEASUREMENT

Three out of our four plans we are considering require measurement and the establishment of time standards for all work to be performed. They are the Measured Day Work Plan, Fair Day Work Plan and the Wage Incentive Plan. It will simplify matters if I discussed briefly this problem of work measurement. To establish work times, it becomes necessary to take time studies.

Time studies, using one of the stop watch techniques, is a basic means of determining work standards. A more effective and efficient means is to develop standard data from stop watch studies. Standard data permits the rapid and economical application of time values to the various jobs performed in the shop. With it, time standards can be applied even before work is commenced on the job.

A predetermined time system can be developed for the company using the studies. Many plants have purchased and adapted for use in their plant one of the standard predetermined time systems. However, even with a predetermined time system, it is necessary to take a certain amount of time studies. These studies will be required to establish machining times. They are also necessary when developing interference times and delay times, particularly for standards covering indirect labor operations. Under no circumstances, can we completely eliminate the use of stop watch studies if we are to apply standards on both direct and indirect labor operations.

If the standards are set directly from time studies, an area for disagreement is present. During the time study, the operator's performance must be evaluated (must be rated) to the plan concept of normal. Without such leveling, the time study is meaningless. This rating of an operator's performance during the time study is always a potential area for dispute. The use of standard data or predetermined time values, once sold to the operators, practically eliminates this area of dispute.

Now it is amazing how many plants do not have their plant concept of normal anchored down by the use of bench marks. Without such bench marks how can we be assured that all the time study men are evaluating to the same normal?

The Unions are quick to take advantage of a situation where the time study men are not evaluating consistently. They ask for recheck after recheck of a job. They will demand a different man to retime the job. The objective is simple. If one or two elements of a study is rated higher each time a recheck is made, it is simply a matter to keep demanding rechecks until the standard is increased to the point that they are satisfied. Six months or a year later we wonder why the standard is loose.

Using predetermined time values to set your work standards eliminates the problem of evaluating the operator's performance. Although you may eliminate this rating problem you are substituting another. It has been my experience that using a predetermined system requires a continual check of the men to assure that the principles of the system are being correctly applied. This can be best achieved if regular sessions are established where typical jobs are used and everybody has to determine the work time using the predetermined time value applied to the same work method. Failure to make this check may lead to as many inconsistencies as with performance rating. Your best bet is to establish standard data. Then you can be assured of consistency in your standard selling.

Differences of opinion between management and operators will result over time standards regardless whether a Measured Day Plan or a Wage Incentive Plan is used. Needless to say, the more confidence that the operators have in the Industrial Engineering Department's standards setting ability and fairness, the less labor trouble will be encountered. This confidence must be earned. To maintain it is a continuous selling job. It is gained by setting consistent standards.

You may notice I did not say accurate standards. Accuracy is relative. Consistency is far more important. And here I should apologize to Phil Carroll[1] for plagiarizing his expressions. He handles the subject excellently in his book, *Time Study Fundamentals for Foremen*.

Operators compare the amount of work they are expected to do. The pace that they are required to work at to meet the standard. This comparison is made with respect to others in the department. It is made between the various jobs to which they are assigned. The use of standard data reduces inconsistencies in standard setting.

The stature of an Industrial Engineering Department shows up when standards are questioned. If they assume a "holier than thou" attitude, that they never make mistakes, there will soon be trouble. In the first place, none of us are infallible. Secondly, this type of an attitude will create resentment. Resentment of the workers can grow into firm opposition, to the point where serious industrial relations problems will result. As fundamental as it is to keep an open mind, I have continually found the principle violated.

Even under a well directed and administered Measured Day Work Plan or Wage Incentive Plan, periodical disagreements and grievances will arise. The less efficient the plan, the more frequent and intense the problems. The danger is that inexperienced management under pressure will negotiate, loosen up, or otherwise tamper with the time standards. For each grievance resolved in this manner, the seeds are planted for six more disputes. Continuation of the practice will cause the Measured Day Work or Incentive Plan to completely deteriorate. Productivity declines and ultimately costs rise to the point where they can drive the enterprise out of business. To salvage the company, an entire overhauling will become necessary. When this occurs, you hear the blame placed on the "system." It is not the system, it is the way it is handled.

REASONS FOR WORK MEASUREMENT

Why do we use work measurement if it can be so troublesome? It gives us the one common factor—time—which is essential to organize and plan effectively and objectively. We eliminate guess work. Knowing the work time, we can plan and schedule our work through the shop. Machine, tool, and manpower requirements can be calculated. Reliable delivery schedules can be determined. The effectiveness of our operations can be measured. Standard costs of our products can be easily and quickly arrived at. It is an invaluable tool for estimating the cost of new work. Work standards form an effective measuring tool, that in various report form, can give busy top management a "birds-eye" picture of the plant's operations. It is the same aid to modern management that a road map is to the traveler. If you have never traveled the road to your destination, you may arrive there without a road map. The chances are it will take you longer and it will probably cost you more.

In the April 1958 issue of *Mill & Factory*, there appeared an interesting article by Ted Metaxas, Midwestern Editor, entitled "What's Wrong With Industrial Productivity."[3] This article was based on a survey of industrial plants made by *Mill & Factory* with the cooperation of the Industrial Management Society of Chicago. It listed work measurement of direct and indirect labor as a prime booster of productivity and one which was not yet adequately practiced by many companies.

They state further:

> "One respondent said failure to measure work left the work pace up to the employee. By failing to use standard data and time study to measure the greatest number of jobs, many firms were ignoring weapons against overstaffing, work slowdowns, poor methods, and failing to provide a yardstick for worker performance. Analyzing jobs with standard data helps establish the best methods and expedites instruction of the operator.
>
> "Yet, inaccurate or too tough production standards often depressed productivity, the survey indicated—and overly loose standards were an invitation to loaf."

INSTALLATION OF WORK MEASUREMENT

A word of caution to those who might be considering the installation of work measurement, irrespective of which plan you may ultimately use. The effects, however, can be more devastating under a Measured Day Work and a Wage Incentive Plan. Either hire an Industrial Engineer who has successfully made such installations in the past and is thoroughly versed in the problem, or have a reliable consultant make the installation for you. Even if a consultant makes the installation, an experienced Industrial Engineer should be hired to assure its proper maintenance. Do not rely on placing this responsibility on the shoulders of an individual who has never before been exposed to this type of work.

I might also add that good Industrial Engineers do not come cheap. You will have to pay at least the prevailing wage. I personally know of three companies who insisted on hiring a Chief Industrial Engineer on a price basis. In each case, the price was substantially below the going wage. Each found a man. But they found themselves in serious difficulties within a year or two.

Before leaving work measurement, may I suggest for your reading a recent article. The title is, "The Truth About Wage Incentives and Work Measurement." It gives the results of a survey covering 785 plants and 21 industries. The work is that of Industrial Production Editor Robert Rice. It appears in the April 1959 issue of *Factory Magazine*.[2] The survey reveals a wealth of information on this subject.

Time does not permit further dwelling on this important subject of work measurement. Let us examine each of the four plans separately.

DAY WORK PLAN

The Day Work Plan is most effective under small shop conditions. Here the owner or owners can maintain control of the entire operations. Cost consciousness prevails. Profits are predicated on the ability of the owner or owners to most effectively utilize their help and equipment.

As the plant grows in size, this closeness gradually vanishes. At which point it looses its effectiveness depends on the individual circumstance.

A Day Work Plant of two hundred or more employees generally is an area where the Industrial Engineer feels he can effect a good showing. A brief review will show us why.

Instructions to the operator under the Day Work Plan are usually limited as to what has to be done. If the man is new or from another department, he may be shown how to do the job. But even on repetitive operations to make a practice of teaching operators the correct motion pattern, is unheard of. The organization is just not set up to do a good methodization job. It is for this reason that the production of two or more operators performing identical operations may vary as much as 100 percent. This might be shrugged off with "Joe's all thumbs."

The productivity of an operator depends on the amount of work at hand, the effectiveness and cost-mindedness of his supervisor. Let us assume that there is plenty of work and this job is in a hurry. With good relationship existing between supervisor and operator, the operator will put forth a good effort. Every bit as good as under other plans. The relationship will influence the effort. When work is slow, the effort and productivity both fall off. There is no hesitation to stretch out the work.

My observations have been that available work must fall off very substantially and for an extended period for the average foreman to take any steps to adjust his manpower. More often the order for such an adjustment comes from someone higher up.

The desire to stay on the "right side" of his men is normally stronger than cost consciousness. It is not that the foreman lacks loyalty to the company. His men are closer. They are present. The company is apt to be a third person.

Management has no true gage of a department's or individual operator's efficiency under the Day Work Plan. There is no tool to measure it with. If a job lot method of costing is used, the fluctuation of the cost between lots may alarm management. The cause is always explained. But unfortunately by the time the cost is developed, nothing can be done to correct the problem.

PRODUCTIVITY UNDER DAY WORK PLAN

Using the scale I outlined earlier, it is my experience that the productivity of the average Day Work Plan is somewhere between 40 to 48 percent.

Why is productivity so low? In one shop I was familiar with, for example, there were bench lathes and drill presses in the Assembly Department. It was not uncommon for an assembler to remachine a finished part. He would plug holes and redrill them to a new location. Parts would be re-turned or rebored to new dimensions. In this plant, the prints were not being kept up to date. If somebody in the machine shop did not remember that the print was incorrect, the parts would be machined incorrectly.

Productivity was low not because the men lacked a willingness to work. Rather time was not being effectively used. The measurement of the effective work, the highlighting of waste, the elimination of idle time, these are some of the factors which work measurement calls to management's attention. Under the Day Work Plan, this tool is lacking.

If work standards are not provided to operators, or if they otherwise have no indication when their performance is not satisfactory, they will establish their own pace. This pace lies considerably below the performance that one may expect for a fair day's wages.

I repeat, that in small owner-operated shops, the Day Work Plan has its application. In large plants, it does not meet our five requirements for maximum productivity. Methodization is usually lacking. Job instructions are at a minimum. Work effort will depend on the amount of work on hand and relationship between foreman and operator. Effective management controls are absent.

Perhaps in the Day Work Shop you have in mind there are no lathes in the Assembly Department. But unless it is an exceptional plant, careful examination by a competent Industrial Engineer will show up reasons why they are not obtaining maximum productivity.

I have heard low overhead given as an advantage of the Day Work Plan. Personally, I would rather have to apply 200 percent overhead to 1,000 hours of direct labor than 100 percent overhead to 2,000 hours of direct labor. So would you.

Under a Day Work Plan less industrial relation grievances should arise than under the Measured Day Work or Wage Incentive Plans. But what a price to pay for it!

MEASURED DAY WORK PLAN

The Measured Day Work Plan can be considered as a modification of Day Work. This Plan introduces the element of time. The correct measurement of all tasks presents a comparison of actual performance to a standard. It sets off a series of reactions.

In the course of measurement, inefficiencies of our methods and procedures as well as interferences to maximum operator effectiveness become evident. It presents the opportunity for correction. Measurement of a task challenges the imagination for better methodization, simplification, and occasionally elimination of the work.

If operators are to be expected to meet the standards, thorough job instruction becomes imperative. No monetary incentives are given for equaling or exceeding the production called for by the standard. Therefore the foreman must guard against production robbing factors such as using poor job layout, improper methods or motion patterns, inadequate tools, incorrectly machined parts, or other interferences.

The same time standards used as work goals also can measure the efficiency of the individual, department, and the plant. They provide the necessary basic information for effective planning, scheduling, and inventory control. The management controls are available. It is one of the five requisites for maximum productivity.

Modifications of the Measured Day Work Plan have been used. One adjusted the operators base rate range depending on their performance for a prior period. These periods varied up to several months. The operators were receptive when their rates were increased. But if the performance warranted a downward adjustment that was a different matter. I am not acquainted with any such plan in operation today.

PRODUCTIVITY

The productivity under Measured Day Work Plans varies substantially. For the average plant, it ranges from 65 to 80 percent. Generally it is a long hard climb to get it up to the 80 percent area. I have known of plants that reached 90 percent performance.

The type of work performed will have a substantial bearing on the plant efficiency. Mechanically paced line operations can generally be brought up to a higher performance than individual operations. The same applies to multi-machine and machine controlled jobs, particularly if the operator's chore is to load and inspect only.

PROBLEMS

The Measured Day Work Plan has all the problems of maintenance and selling of standards as found under the Wage Incentive Plan. The standard setting group is under the same pressure to loosen up the standards. The same problems are encountered when taking actual observations in the shop. All the arguments regarding the sufficiency of the time allowance are made by the operators or union representatives. Group resistance and in some cases, slow downs, are weapons used by the workers. And as under the Incentive Plan, too often the battle is over standards which—unchanged—they eventually meet. In my opinion, beyond a fixed and expected constant, that will occur under the best administered plans, the degree of difficulty encountered is in direct ratio to the amount of abuse management has permitted the system to be subjected to in the past.

Some companies use the work standards only as an indication of individual and departmental efficiency. They make no serious effort to increase operator productivity to the standard. In such cases, employee and union grievances pertaining to standards are at a minimum. Ultimately the operators even lose active interest in the standards. The productivity of these plants is usually at the lower end of the range I gave as attainable under this system. They did receive a productivity pickup with the installation. Operator effort, manpower requirement, and interferences are watched more closely than under the Day Work Plan.

The one advantage of the Measured Day Work Plan over the Wage Incentive Plan is that earning inequities do not exist between measured and nonmeasured workers in the shop. These inequities can become quite bothersome. They create the greatest difficulty between unskilled help on incentive and skilled help on day work.

Strive to improve operator performance under the Measured Day Work Plan to the work standards and you can expect practically all the headaches of a Wage Incentive Plan. But you will still not obtain, on the average, the same production.

FAIR DAY WORK PLAN

The Fair Day Work Plan is an outgrowth of the Measured Day Work Plan. As I mentioned earlier, it does not use monetary incentives to obtain maximum productivity. Although times standards are set, they are not presented to the operators. They do not know what they are. When I first heard of this plan, it sounded like a radical departure from what we were doing. In a sense, it is. The question immediately arose how do you get the operator to work? And, what kind of productivity do you obtain? Although I had to wait for the answer, I can say to you that productivity is good enough to warrant your further interest.

The Fair Day Work Plan is not new. It originated at the A C Spark Plug Division of General Motors Corporation. It has been used there since

1941. They are highly satisfied with the plan. From the A C Spark Plug Division, it has spread to other plants both in and out of General Motors. I have been involved in such an installation for one of the companies I worked for.

Before we made our installation we visited the A C Spark Plug plant, also several others using the Fair Day Work system. Their results and enthusiasm, plus certain problems we had, resulted in our making an installation. It is currently in operation in plants manufacturing a wide variety of products. Its applicability to various machine shop, assembly and even processing operations is demonstrated.

Let me first retell the A C Spark Plug story, drawing heavily on a paper prepared by Jack Waite who at the time was in the Work Standards Department.

The incident which gave birth to the Fair Day Work concept occurred in 1937.

A Measured Day Work System was in use. The operators knew the work standard. Supervision quoted pieces per hour or per shift expected, quite emphatically. Seventy-five girls were performing identical machining operations. Two girls were not meeting the expected production. They even worked part of their rest period and lunch hour. They were daily reprimanded. In those days, it was assumed that operators who did not make the expected quota were either lazy or loafers.

What brought the situation to a head was the other girls. Realizing these two girls, in spite of the effort they put forth, could not make the standards, they all dropped their productivity to the same level. It took a long time to work out of this problem, but it was the birth of the Fair Day Work Plan.

By taking film studies, the reason for the differences of production was apparent—the method or motion patterns of the various operators were different. The fastest used the least amount of motions. Actually with less effort—they produced more. By proper instructions instead of criticism, the two girls were able to improve their production. They finally were able to make as many pieces as the others.

The development and refinement of the Fair Day Work concept took several years. The works manager's and general manager's encouragement and cooperation helped create a new approach to an old problem.

STATEMENT OF POLICY

In the A C Spark Plug standards instruction manual is a statement of policy which reads:

1. We expect from each employee a fair day's work using our methods; a day's work that is fair to the employee and fair to the company.
2. We ask no one to work at anything but a normal speed or tempo.
3. If the employee gives us normal work effort and time using the prescribed method, then the quantity produced becomes the responsibility of the supervisor.
4. No person who is sincerely trying to give a fair and full day's work effort is to be criticized for failure to achieve a production total.

They define a Fair Day's Work as:

1. A fair day's work is one where each employee performs a full day's work from the authorized starting time to the authorized quitting time using the prescribed methods of performing the work with normal work effort and remaining on the job except for necessary personal needs.
2. A day's work that is fair to the employee and fair to the company takes advantage of *improvements* (resulting from methods, tooling, material, engineering, layout) *immediately* without regard to time study and production counts, as long as we do not demand more than a normal effort and a full day's work.

RESPONSIBILITIES

To carry out this policy both the workers and management have certain responsibilities. They are spelled out.

Workers Responsibilities to Company are:

1. Start work on time.
2. Apply himself each hour except for reasonable personal needs.
3. Follow the prescribed methods.
4. Maintain quality requirements.
5. Adapt himself willingly to improvements and changes.
6. Obey shop and safety rules.
7. Work until designated quitting time.

Management's Responsibilities to Employee are:

1. Satisfactory working conditions.
2. Adequate tooling, facilities and equipment.
3. Proper flow of material and parts.
4. Correct work place layout.
5. Designated method or procdure for doing the work.
6. Explanation of a fair day's work.

The importance of *mutual* responsibility is absolutely necessary for the successful application of a fair day's work policy.

TIME STUDIES

Time Studies are made to *assist* supervision. It is the foreman's responsibility to obtain a fair day's work from an employee. If an operator is hampered by delays or not using the method, he will not make the standard.

When operator performance does not come up to expectancy the foreman investigates two major areas of trouble. The first are job conditions which may create the condition. They may be machine trouble, stock flow, improper layout, substitute material, changeovers, faulty tooling, pieces not to print, and so forth. The foreman can either correct these problems himself or call for the assistance of the related service department.

The second cause for not meeting work standards are employee work habits. The foreman must check if the employee is starting late, is away from his job, is wasting time, is using improper methods, is not following instructions or is quitting early.

The foremen are thoroughly trained as to their disciplining responsibility. They can only discipline for starting late, failure to follow instructions, absence from job. Under no circumstance is an operator disciplined for failure to produce a specific amount of production—loafing, or not producing to a standard—laziness.

Jack Waite states: "We recognize that to get a fair day's work is not always an easy matter. However, we must consider the majority, not the minority. I would say the minority constitutes not more than 5%, and corrective action—verbal warning first, then the reprimand procedure will, for 99% of the offenders, correct their thinking."

All new hires are subjected to tests by A C Spark Plug's Personnel Testing Department. The results serve two purposes. They help in job placement. They assist in separating misfits, individuals who would never be happy working in a plant regardless of the job on which they were placed.

This brings us to an interesting contention maintained at A C. It is that there is no such thing as a slow operator.

Jack Waite qualifies this statement:

1. The job must not have such a high degree of skill that it is beyond the capability of the average or normal operator.
2. The operator must use the prescribed method and motion pattern.
3. The operator must have the desire and physical qualifications to exert normal work effort.

Camera studies by them revealed that the slow operator was introducing, quite unconsciously, extra motions, which accounted for their slowness. The Work Standards and Method Engineering staff of General Motors made a project study on tempo evaluations. It verified A C's thinking. That the speed of movements of properly selected and trained operators, within limits, will be the same.

A C Spark Plug is sold on the Fair Day Work Plan. It has eliminated problems on:

1. Changes in multiple machine rate assignment.
2. Changes in line balance on progressive lines.
3. The setting of standards when new products or new lines are first put into production.
4. Obtaining improvement hours in their manufacturing departments.
5. A pieces per hour goal for operators—the goal is a fair day's work "peace of mind" not pieces per hour.
6. Employee suggestion participation—A C for three years was number one among the manufacturing divisions in General Motors—reflecting employee attitude.
7. Revising work standards without any contractual obligations except—"on the basis of fairness."
8. Grievances on work standards have disappeared.

Are among these problems some that you would like to eliminate in your plant?

PRODUCTIVITY

What productivity may be expected under the Fair Day Work Plan? I will approach this question categorically.

Let us consider mechanically paced assembly line operations. We had as many as 40 operators on one line. After the normal start up, productivity will range between 95 to 102 percent on our high task scale. I have observed productivity that matched the best performance I have seen on lines working under Wage Incentive.

However, to obtain this type of performance, your Fair Day Work Plan foremen work harder. The incentive operators called to the line supplier's attention the fact that parts on hand were running out. A shut down for lack of parts affected his earnings. There was no uncertainty about their demand for more parts. Under the Fair Day Work operations, my experience and observations has been that this is lacking. A line shut down is an additional rest break. The foreman has to be alert to prevent such shut downs.

On competely manual operations we had our greatest problems to improve productivity. The average performance ranges between 90-92%. The same applied to fast punch press operations.

The performance on machining operations where a substantial portion of the work is manual ran surprisingly higher, 97 to 98 percent. This included spot welding, lathe, milling, grinding and drilling operations.

Productivity on automatic equipment will vary. It will depend more on the complexity of servicing rather than on number of machines run. Productivity affected by these factors will vary between 90 to 98 percent of practical machine capacity. In other words expected productivity allowing for tool changes, material loading and so forth.

On automatic presses—operators running two at a time 90 to 95 percent of capacity is obtained. Automatic screw machines, the operator servicing two or more, depending on kind and also setting up, 90 to 92 percent of capacity has been the best obtained.

Please note that the measurement of productivity for automatic equipment is not on the high task scale. It cannot be. Rather on the basis of maximum expectable productivity or practical machine capacity.

Regarding our five requirements for maximum productivity: under the Fair Day Work Plan they do attempt to develop the best method. Proper instructions are a must. A good work effort is obtained. Elimination of controllable interferences is one of a supervisor's prime functions. Adequate controls are present.

The system also has the advantage of eliminating many of the problems of work measurement and disputes over standards.

The problems with the Fair Day Work Plan is that belief in it must be universal among the management of a plant. This belief must radiate downward through to the first line supervisors. This lacking, the plan will suffer. New Supervision will not be as carefully selected or receive sufficient training. Well instructed foremen are the foundation of this plan.

Inadequate attention to methodization can be detrimental. The performance records will not reveal the fact that methodization was not the best. The operators will follow the methods and give satisfactory performance. There is no incentive to deviate from the plan—to make an extra dollar—if the methodization is not as efficient as it might be.

In conclusion, the Fair Day Work Plan eliminates squabbles and grievances over standards. The production potential is higher than under the average Day Work or Measured Day Work Plans.

WAGE INCENTIVES

Under Wage Incentives, productivity should equal or somewhat exceed 100 per cent on our scale. This applies to manual and partial machining operations. Production from automatic equipment should equal 98 to 100 per cent of practical machine capacity.

There are those who contend this type of equipment should not be on incentive.

Is there a potential of increasing the yield through more effective operator attention? Can it be done economically? If the answer is yes, it makes good business sense to apply incentives.

Wage Incentives will give you the productivity I mentioned but only if your system is properly administered. The standards must be serviced as changes take place. They must be changed to the extent of the change.

Failure to maintain the effectiveness of the Wage Incentive Plan will quickly eat away the productivity. Yet only 162 plants of 300 answered yes to the survey question, "Do you review standards periodically?" This was Mr. Rice's finding as summarized in Factory's April Addition. [1959: Editor].

But of these plants only 75 percent made bona fide on-the-spot checks at least once a year. It is amazing to me that so many gamble with a factor having direct bearing on company profits.

Another survey question was answered by 249 plants. It was: "In general, what are the results of Wage Incentives in your plant?" It reduced costs, 96 percent of the companies said. Standards help supervision, 95 percent replied. It improved employee morale, 77 percent contended, while 44 percent admitted it increased grievances. From this we can conclude that although incentives resulted in more gripes the employees did not object if it was incidental to an opportunity to take home more pay for extra effort expended on the job.

CONCLUSION

Is there something better than monetary incentives for maximum productivity? In no case is maximum productivity easy to attain. Management must work hard to secure it.

Under certain circumstances—mechanically paced operations—the Fair Day Work Plan can equal the performance received under incentives. We have not found any system that will exceed the productivity attained under Wage Incentive.

If you do not maintain your Wage Incentive Plan, maximum productivity will elude you. But does not that hold true for any plan you may substitute for it? I am convinced that Wage Incentives provide the greatest maximum productivity potential. Almost as good a productivity can be attained through a well administered Fair Day Work Plan. The same management effort applied to a Wage Incentive plan will hold grievances to a surprising minimum. And you will end up with at least 10 percent greater production from your employees with the same capital outlay for plant and equipment.

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PRODUCIBILITY ANALYSIS – A CHALLENGE TO INDUSTRIAL ENGINEERS

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PRODUCIBILITY ANALYSIS – A CHALLENGE TO INDUSTRIAL ENGINEERS

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MUCH has been said and written about the importance of an improved quantitative approach to productivity. Attempts have been made to use this approach in measuring and predicting progress of the manufacturing functions.

One significant attempt to measure manufacturing progress has been the use of the "aircraft learning curve" originated by Dr. T. P. Wright[1]. This theory was well analyzed by Professors Conway and Schultz of Cornell University[2] in an article which highlighted the use as well as the limitations of this approach.

While it is recognized that problems do exist that limit the accuracy of data derived from using the learning curve approach it is, nevertheless, more accurate than the use of estimates and "budget" or "realization" factors.

To our knowledge not much has been done to use learning curves as a tool for making comparative cost estimates for use in guiding product designers towards the most producible design. This paper will deal with this use of the learning curve in a function which we call "Producibility Analysis".

The term "producibility" is relatively new and it is, therefore, not surprising that there is some confusion and misunderstanding as to its true meaning. In fact, it is already applied to two totally different factors:

(a) Design producibility—defined as the inherent attribute of a design which renders it capable of efficient and economical production, the rate of which may be rapidly accelerated and maintained.

(b) Manufacturing producibility—defined as the ability of a factory to produce efficiently, economically, and promptly; and to readily accelerate and maintain high rates of production. This also implies the availability of adequate tooling and supplies of material.

In order that the designer can meet these producibility concepts, he must adhere to certain fundamental rules:

(a) *Seek simplicity*—of all functional and physical characteristics of the part or assembly.

(b) *Determine the best production method*—by designing for the most economical method available, with allowance for inherent design limitations.

(c) *Analyze specific material or materials*—carefully selecting the materials that suit the production method as well as the design requirements.

(d) *Minimize production steps*—by designing for the minimum number of separate operations in machining, forgings, castings, fabrication or assembly.

(e) *Eliminate handling problems*—by designing for ease of locating, setting-up, holding or handling parts.

A producibility analysis measures the cost of comparative designs thereby providing the designer with a guide to the most economical and producible design. These guides are usually written up as a Producibility Analysis Memo or Report which constitutes a formal presentation of the analysis and its considerations.

In order to fully understand and appreciate the end results of such analyses, certain fundamental concepts must be recognized:

(1) The learning curve theory is applied.

(2) Cost must always be tied with quantity.

(3) Project plan or total quantity must be determined, and only this quantity will be used in making cost decisions.

(4) Early serialization is most important since a potential saving can turn into a loss through delays in putting the proposal into effect.

LEARNING CURVE DEVELOPMENT

The basic theory of the learning curve is simple. Applied to human endeavor, it is known that a worker learns as he works; and the more often he repeats an operation the more efficient he becomes, with the result that the direct labor input per unit declines. This holds true whether the industry is aircraft, metalworking, textile, candy-making or other. What was not known until a decade or so ago is that the rate of improvement is regular enough to be predictable. The pattern that this rate of improvement follows was found to be consistent between doubled quantities.

It was also found that human labor was not the only item of product cost that possessed a "learning" factor. For example, it can be said that a machine tool "learns" when a 4-unit per hour tool is replaced by a 10-unit per hour tool; a design "learns" when a present 12-part assembly is redesigned to be made from 4 parts; tooling "learns" when more advanced and efficient jigs and fixtures have been developed; and materials "learn" when the latest, more adaptable and easier worked materials are substituted for present materials. It is true that all these items tend to improve productivity and shown graphically would appear as a series of steps.

Since this progress can be measured, it can also be plotted on graph paper. Learning curves shown on arithmetic grid paper are difficult to read (Fig. 1) and for this reason are usually shown on log log paper (Fig. 2).

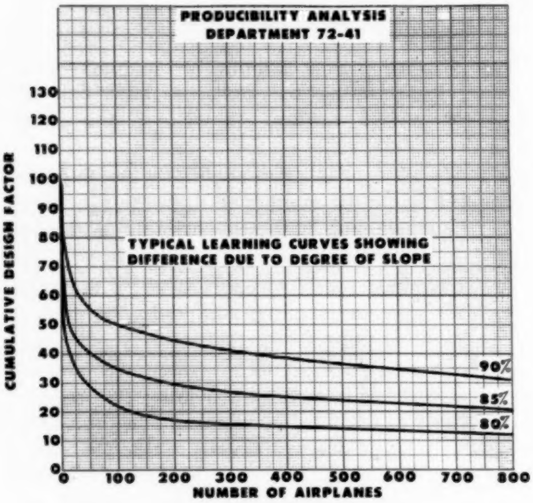


Figure 1

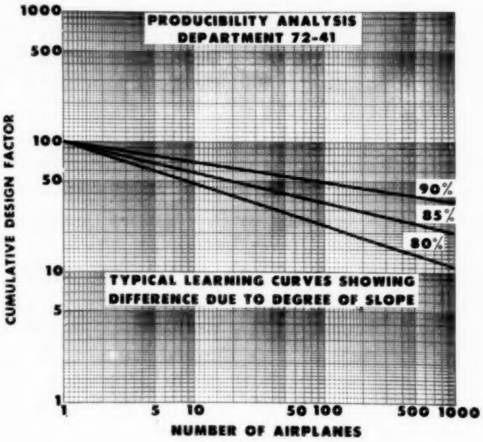


Figure 2

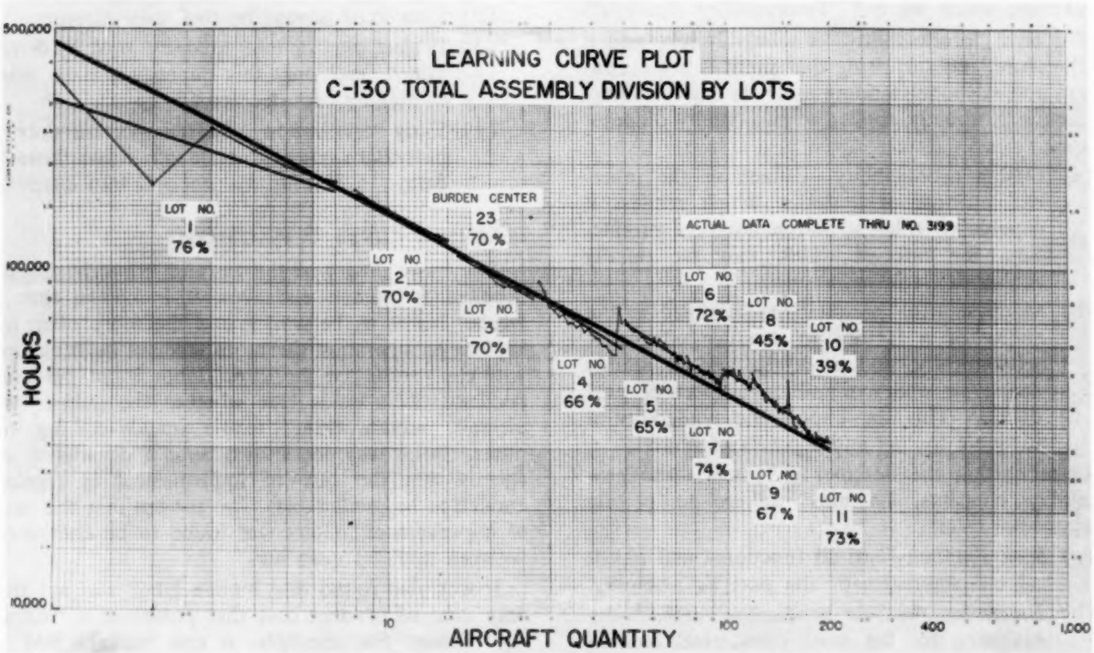
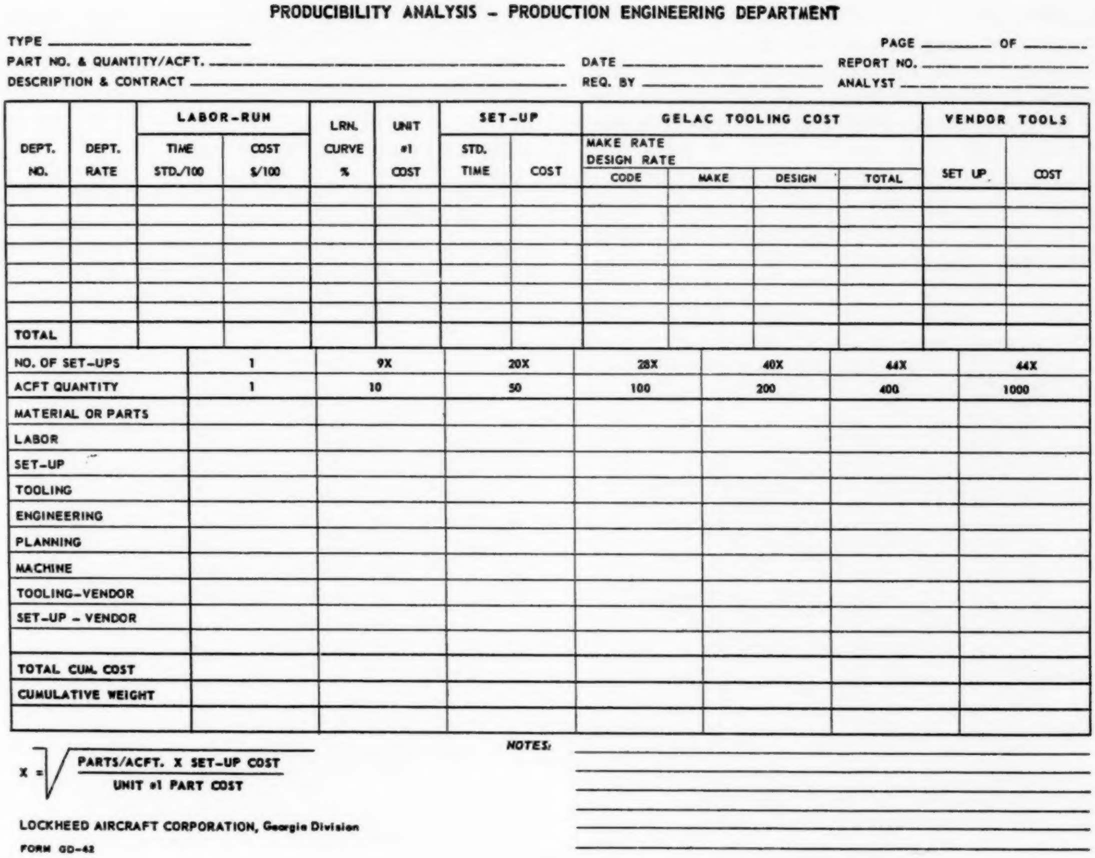


Figure 3



PRODUCIBILITY ANALYSIS – PRODUCTION ENGINEERING DEPARTMENT

TYPE ____________ PAGE ______ OF ______
PART NO. & QUANTITY/ACFT. ____________ DATE ____________ REPORT NO. ____________
DESCRIPTION & CONTRACT ____________ REQ. BY ____________ ANALYST ____________

		LABOR-RUN		LRN. CURVE %	UNIT #1 COST	SET-UP		GELAC TOOLING COST				VENDOR TOOLS	
DEPT. NO.	DEPT. RATE	TIME STD./100	COST $/100			STD. TIME	COST	MAKE RATE DESIGN RATE				SET UP	COST
								CODE	MAKE	DESIGN	TOTAL		
TOTAL													

NO. OF SET-UPS	1	9X	20X	28X	40X	44X	44X
ACFT QUANTITY	1	10	50	100	200	400	1000
MATERIAL OR PARTS							
LABOR							
SET-UP							
TOOLING							
ENGINEERING							
PLANNING							
MACHINE							
TOOLING-VENDOR							
SET-UP – VENDOR							
TOTAL CUM. COST							
CUMULATIVE WEIGHT							

$$X = \sqrt{\frac{\text{PARTS/ACFT.} \times \text{SET-UP COST}}{\text{UNIT \#1 PART COST}}}$$

NOTES: ____________

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FORM GD-42

Figure 4

COLLECTION OF HISTORICAL DATA

Primary effort in establishing a producibility analysis program lies in the collection and analysis of cost data, usually in the form of hours expended as the part or assembly flowed though the various operations.

For example, the learning curve for the assembly division was developed by plotting the hours required for each airplane as it passed through the assembly organization (Fig. 3). It was determined that the reason for a jump in hours for the first ship in each lot was due to an accumulation of design changes that are collected for incorporation at the beginning of a new lot quantity. Average slope was determined by using the method of least squares.

It is noteworthy that the 70% learning curve for assembly as calculated from historical data was very close to the estimated learning curve that was predicted three years prior to production and based on learning curve data collected from another model aircraft.

Similar curves were developed for all departments and cost centers in fabrication and sub-assembly.

CALCULATION OF COSTS

Special analysis sheets were developed (Fig. 4) for use in tabulating data and making calculations. No attempt will be made here to go into detail concerning usage of this form. Major items of interest include the following:

(a) All items of cost are considered, including engineering and planning costs.

(b) Costs are calculated for seven quantity points (1, 10, 50, 100, 200, 400 and 1000).

(c) Existing plant organizations and their reports are utilized to as great an extent as possible in order to eliminate duplication of effort. For example, the production control organization furnishes operation sheets for each part which show the department routing, standard times allotted and tooling needed. The finance organization provides departmental rates, which include overhead, and a tabulating tape provides the hours actually used for tool design and tool manufacture.

GRAPHIC PRESENTATION

As pointed out previously, we are only interested in comparative costs as they occur at project plan quantity. True comparisons can more readily be seen by plotting the totals from the analysis sheets on graph paper.

Cumulative totals as shown on the analysis sheet can readily be converted to unit average by dividing the quantity into the cumulative total. These curves when plotted on arithmetic paper (Fig. 5) are very difficult to interpret and for this reason are more often shown on log log paper (Fig. 6).

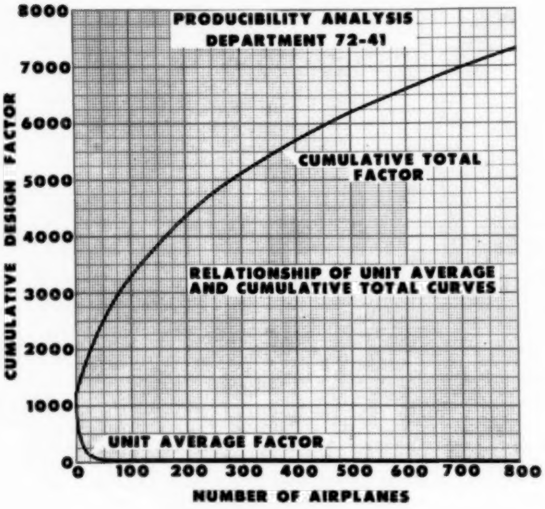

Figure 5

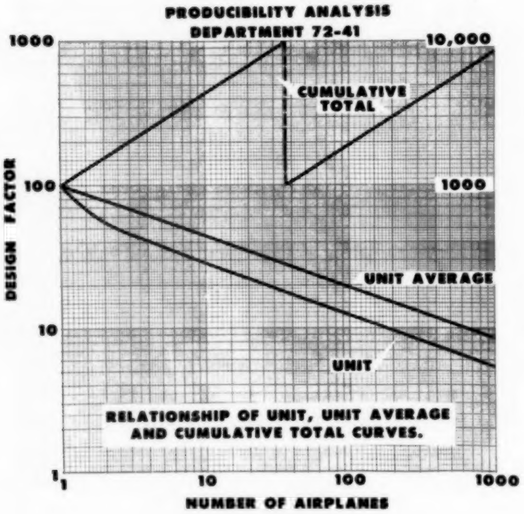

Figure 6

Unit curves are not used for purpose of cost analysis because they do not reflect the cost of previous units. Unit average on the other hand includes all prior costs.

COMPARATIVE COST ANALYSES

Requests for comparative cost analyses will normally originate with the Production Design Engineer who is in need of a cost comparison between two or more designs for a given part or assembly. A comparison graph (Fig. 7) showing two designs from inception points out how proposed design "B" is cheaper than proposed design "A" at the project plan quantity of 800 aircraft.

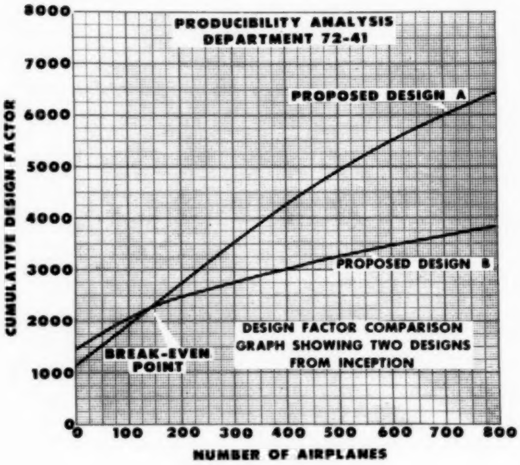

Figure 7

More often, a comparison is required between an existing design and a proposed design. As can be seen on Figure 8, the present design curve

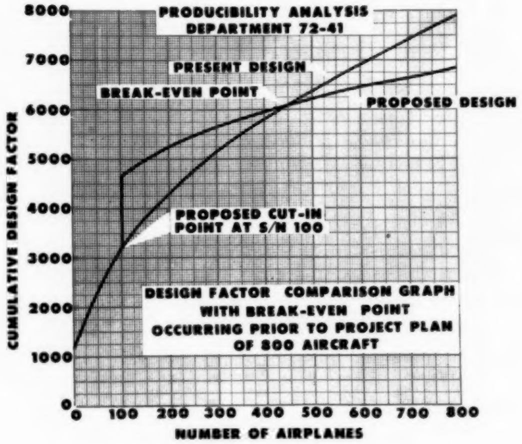

Figure 8

depicts some initial costs (tooling, engineering, planning, etc.) that occur prior to the first production unit. Slope of this curve is plotted from the seven quantity points shown on the analysis sheet for the present design. A proposed design, which can be cut in at the 100th unit, is plotted by using the seven quantity points from the analysis sheet for the proposed design. Again some initial costs are shown (engineering, tooling, re-work, etc.) and since these are cumulative curves, these costs are added to the curve for the present design. Study of the completed graph indicates that the proposed design is cheaper—at the project plan quantity of 800 aircraft.

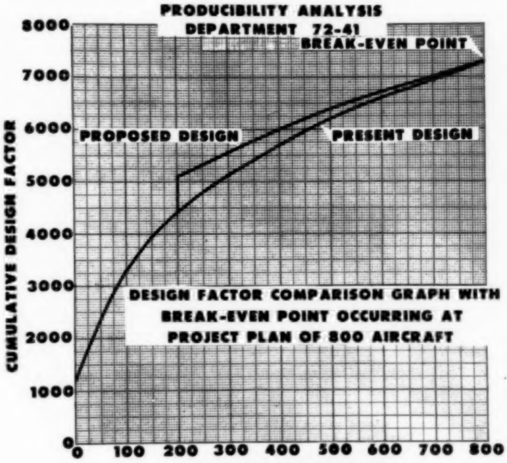

Figure 9

Of course, there will be occasions when the proposed design breaks even at or near the project plan quantity (Fig. 9) or does not break even at all within the project plan (Fig. 10). In such cases, the proposed design would not be recommended because of the cost penalty involved. It must be pointed out, however, that other factors in the proposed design may be of sufficient value to warrant recommendation despite the additional cost. In these cases we would at least know the cost of the proposed advantages over present design. Experience has shown that in most cases the simplest and best design is also the lowest in cost.

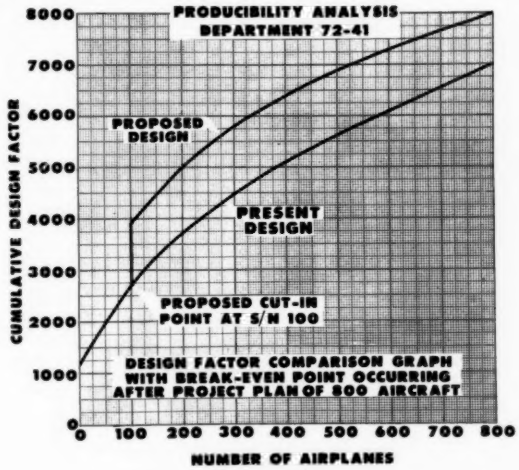

Figure 10

Once it has been determined that a proposed design should be adopted, it should be scheduled into production as rapidly as possible. A delay in placing the change into effect can result in a substantial saving being nullified and, in fact, could result in a loss. Figure 11 shows the effect of such a delay. A substantial saving that was anticipated from a cut-in at ship 100 was cut in half when the serialization was delayed to ship 150. A further delay to ship 200 would, in effect, cancel out the entire saving, and could even result in a loss.

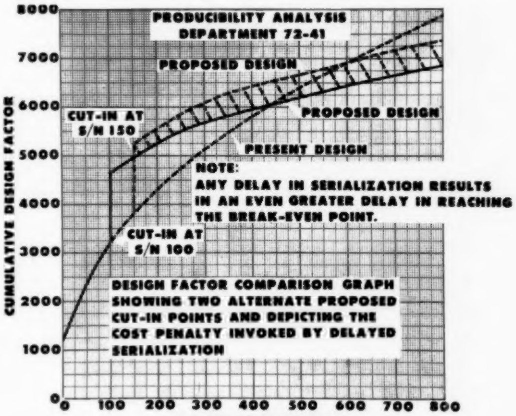

Figure 11

This characteristic becomes especially important towards the end of a project plan for a particular model. A proposed design may have excellent potential for a large cost saving except for the fact that it was suggested too late for installation in sufficient time to realize the savings. In these cases, it is important that the proposal be earmarked for use in a similar situation on a future model when it can be placed into effect at inception of the design.

It was said earlier that too many engineers fall into the trap created by comparing two columns of figures representing the present and proposed methods. Without tying cost to quantity, the above method can be true only at one quantity condition and as a result may lead the engineer into making the wrong recommendation. Figure 12 illustrates the effect of quantity on the percentage of total cost. At the first unit, as would be expected, the highest items of cost are tooling (30%), engineering

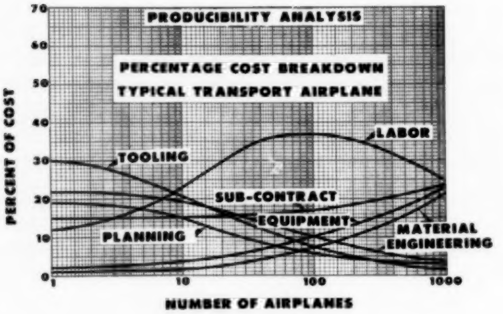

Figure 12

(22%), and planning (19%). At the 1000th unit, the above items are all under 3% of the total cost, being replaced by labor (25%), parts (24%), equipment (23%), and material (21%).

TWO TYPES OF COST SAVINGS

Cost analyses can be broken down into two distinct types of savings:

(a) Corrective action—those savings resulting in a change from the present method.

(b) Preventive action—those savings resulting from design or method revisions prior to the actual start of production.

Obviously, the preventive action type is the best since it precludes the spending of any money doing something the "wrong" way. At the same time, this is the hardest type to measure and to "sell". Corrective action savings are measured by simply taking the difference between the present method and the new improved method.

Every now and then we come across a case of preventive action that resulted in substantial savings. A typical example is shown on Figure 13.

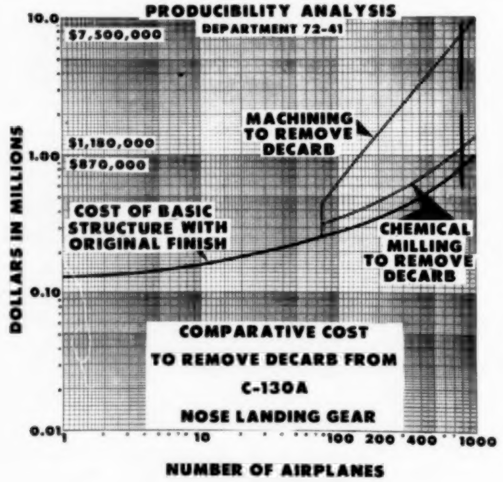

Figure 13

Our stress people were concerned about the hydrogen embrittlement on the nose landing gear and proposed that they should be machined. As can be seen, this would have cost us $7,500,000 for the project plan quantity of 800 aircraft. A proposal to use chemical milling brought the estimated cost down to $1,180,000. However, this method was still in development and was not ready for production operation. A producibility analysis pointing out the high costs involved resulted in cancellation of plans for machining and forced a re-design which solved the problem.

Another problem resulted from a failure of the fulcrum on the nose landing gear cylinder. Producibility analyses made in conjunction with proposed "fixes" (Fig. 14) led the designers to adoption of the cheapest proposal, a re-design incorporating an internal plug.

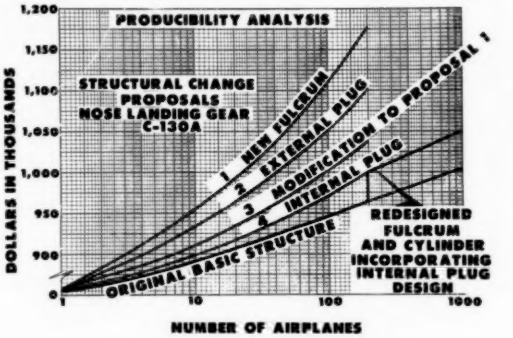

Figure 14

A final example (Figure 15) illustrates several design efforts to provide an engine shroud for the

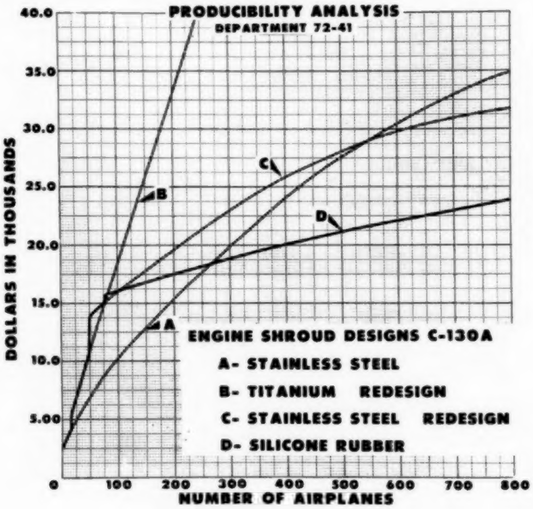

Figure 15

C-130A Hercules. Again, these studies enabled the design organization to make the most economical choice.

NEED FOR RAPID ANALYSES

While excellent service was provided by means of these analyses, the design organization was still faced with a need for a system of rapid analysis that would enable them to make the right decision from a producibility standpoint without delaying the release of designs. This is extremely important because of the tight schedules facing the project design organization for release of production drawings.

This problem is being alleviated by development of a Factor Design Handbook. As each comparative analysis is made, a page for each method is developed for the handbook. These pages include a sketch or picture of the part or assembly in question and unit average curve which includes all items of cost for each of the seven quantity points on the producibility analysis sheet. This curve has been expanded to plus 5% and minus 5% which in effect gives a 10% band. This is felt to be well within the desirable limits of accuracy for these rapid comparisons.

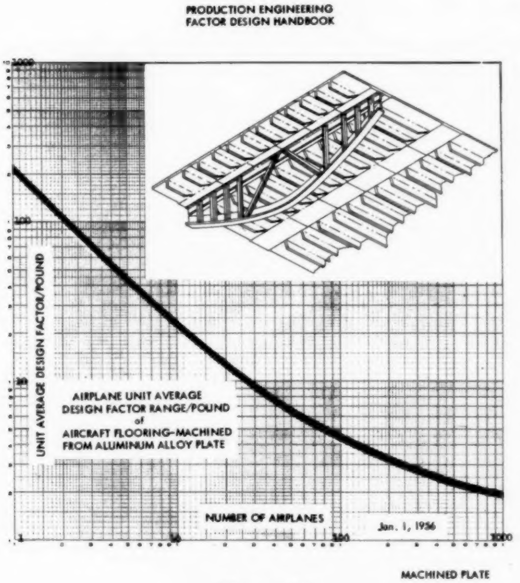

Figure 16

Sample pages (Figures 16 and 17) of the Factor Design Handbook can be used to illustrate how this method can produce rapid analyses. Original design of the C-130 cargo floor provided for machining of the floor from aluminum alloy plate. Improved design provided for a built-up sheet aluminum flooring with Drivmatic riveted stiffeners. The original design did not meet the requirement of good producibility because of the inability to rapidly expand production. The fact that Onsrud or K & T Panel Mills were needed for machining of the aluminum plate, limited the production quantity to the number of machines on hand. Procurement time of approximately two years for additional tools negated the chance for rapid acceleration of production quantities.

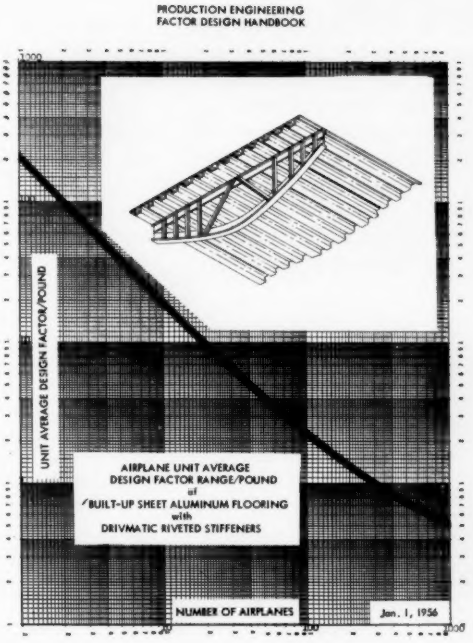

Figure 17

The method for using these pages is simple: First of all, seven points are taken from the curve on Page 3.301 and plotted on a piece of graph paper. Then the same seven points are taken from the curve on Page 3.302 and plotted on the same graph paper. The final result will appear as in Figure 8. In reading the points from the band it does not matter whether or not you read from the top, bottom or an imaginary mean line within the band, as long as the line selected is used consistently. This system enables the analyst to make a comparative cost analysis in about 15 minutes whereas it could take several days or in some cases weeks if it had been necessary to make the complete investigation. It is interesting to note that this system works for any similar structure and does not necessarily have to be the actual history of the analysis in question.

No attempt has been made at this time to go into the detailed development of data collection and analysis methodology. Rather, we have tried to illustrate the value of this tool of "producibility analysis" for providing guidance to the design organization. We cannot stress too much the importance of providing this coverage early in the design stage, preferably in preliminary design. It has been said that trying to apply good producibility after a design has been released is like trying to put a bridle on a running horse. The system is far from perfect and many refinements are being added daily. However, the system provides a definite challenge to Industrial Engineers who will find in "producibility analysis" another good tool by which they can increase productivity.

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COMMUNICATION THEORY AND ITS PRACTICAL APPLICATIONS

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In 1940 he joined Convair as an electrical engineer later changing to Lockheed Burbank. Leaving Lockheed in 1942, he served the Utility Appliance Corp. as Chief Plant Engineer until his entry into the U. S. Navy in 1944. In 1946 he left the U. S. Navy and became a consulting engineer for Inet, Inc. which he founded and was president of from 1946 to 1953.

Since 1946 he has been a member of the staff of the Department of Engineering at UCLA. Currently he is an Associate Professor.

COMMUNICATION THEORY AND ITS PRACTICAL APPLICATIONS

by ALLEN B. ROSENSTEIN

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BEFORE discussing the practical application of Communication Theory, it will be profitable to attempt to bring this area of engineering endeavor into better focus. Current articles on Information Theory will contain references to the Statistical Theory of Communication, Statistical Quality Control, Statistical Theory of Errors, Theory of Games, and the Theory of Statistical Decisions. Information Theory can be recognized as a branch of Probability Theory. Norbert Weiner[1] believes that Information Theory is properly a general statistical concept of communication and comes under the Theory of Time-Series as a branch of Statistical Theory along with Statistical Mechanics and Quantum Theory.

The relations between the various theories and the present status of Communication Theory has been well presented by Brockway McMillan who has written[2]:

> "One function of theory is to develop methods for solving practical problems. Another is to organize and to make comprehensible the domain of knowledge in which the theory operates. Those who apply theory place their own values on these two functions, but all, in fact, use both. To be solved, even the most practical of problems must be stated in the terms of some underlying logical structure; to solve it, even the most practical of engineers must comprehend this structure and understand the terms thereof.
>
> "The theory of communication offers the engineer a logical structure founded upon circuit theory and upon the theory of probability. Within this structure, it offers him methods for solving certain practical, and even impractical, problems. These are problems of detection. The theory recognizes the operation of detection as that of decision or measurement in the presence of error. This is exactly the problem to which the efforts of mathematical statisticians have been directed since early in the century. Thus the tools of the statistician are available to the engineer; he can now design detection systems, optimum by one of several criteria, for signals perturbed by one of several different types of noise.
>
> "For the case in which the signals to be detected are time-series perturbed by added noise, statistical tools are particularly sharp; theory offers in this limited domain methods of such elegance and power that they transcend even the challenge of the practical problems for which they were first conceived.
>
> "It is scarcely an understatement to say that problems of detection are the only ones for which statistical theory now gives the engineer specific methods of solution. Theory has, however, gone farther than this in organizing his thought.
>
> "In the first place, the theory of detection itself, can be, and recently has been by Middleton and van Meter, imbedded in the more general theory of statistical decision, as developed by the late A. Wald and others. This latter theory, in turn, allows a very general measure of the performance of a detector, derives general relations among methods of detection, and in some cases delimits the domain within which the engineer must search to optimize his chosen measure of performance. All results at present relate to the case in which the list of alternative decisions; i.e., the list of signals, is pregiven and fixed.
>
> "This decision theory of Wald provides a pattern within which one can account for the undesirability of errors in detection by assigning almost arbitrarily an appropriate cost to each error, and to indecision. The cost of error, however, is not the only cost with which an engineer must cope. He also has to reckon the cost of his equipment, either as a first cost, or as an operating cost measured either in money or more abstractly in terms of complexity, liability to failure, or sensitivity to deviations in components. Most such costs depend critically upon the accidents of available technology; it is too much to ask that a general theory account for them in detail. Yet there is one cost of this kind for which an effective accounting is possible.
>
> "When dealing with communication as a service—as distinct from communication as an adjunct to measurement or control—the engineer can fairly assume that revenue is a significant negative contributor to operating cost, and further, that the rate of revenue is proportional to the number of messages handled in a given time. Motivated by these assumptions, the work of Shannon comprehends in a single structure the engineer's view of the process of communication as a service.

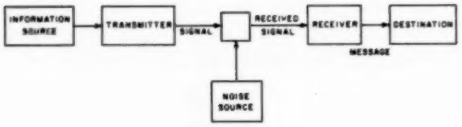


Fig. 1

"Here appears the quantity of primary interest to such communication, namely, the communication rate in effective characters per-unit time. Here appears the operation of modulation, in recognition that the list of alternative signals is not pregiven and fixed; indeed, the engineer designing a communication system has control, not merely over the mode of detection, but also over the actual form of the signals to be detected. Here also appears, and for the first time, the general concept of the received signal as a random entity merely distributed jointly with the transmitted signal.

"Within this framework, Shannon's theory now exhibits a least upper bound to the achievable rates of communication. The bound is a quantity intrinsic to the medium of communication and its accompanying noise; to attain it exploits the full freedom of the engineer both to detect and to modulate optimally."

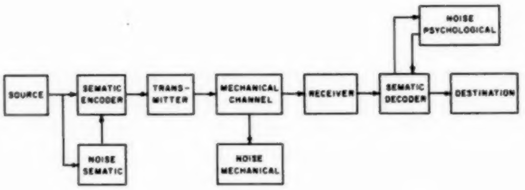
Shannon's Information Theory concerns itself essentially with the problem of the transmission and detection of information. The detection problem is essentially one of determination of the original information or message. L. Brillouin[3] points out that Information Theory ignores the value of the information handled by a system. This element of information value, however, is needed whenever one considers information as a basis for prediction or decision. It is the Theory of Statistical Decisions which is concerned with the meaning and use of information. We see, therefore, two related but different decisions. The first concerns the determination of the information that has been sent through a communication channel and here Information Theory helps us. The second involves a determination of the proper course of action in light of given information. Here the Theory of Statistical Decisions is of some help.

INFORMATION THEORY

The Appendix of this article contains an elementary description of Information Theory as developed largely by Shannon. Although Information Theory ignores the value of the information transmitted by a system, it does give an excellent description of all facets of the system's information-handling capabilities. It is in this connection that the I. E. will find the theory of great value. Since the industrial organization is essentially a large communication system, an understanding of Information Theory gives deeper insight into the operations of the industrial complex. The theory gives excellent grounding for the systems approach to problems. The central premise in Information Theory involves the information transmitting capacity of a communication channel. As long as the industrial problems which we consider deal with the transmission of information, the application of Information Theory is found to be convenient and useful. Those factors such as coding and decoding, noise, redundancy, and channel capacity which are important in a mechanical system will be equally important in determining the performance of the industrial system. Of particular interest is the ability of Information Theory to provide a good measure for understanding and predicting the behavior of the human information processing links in the system.

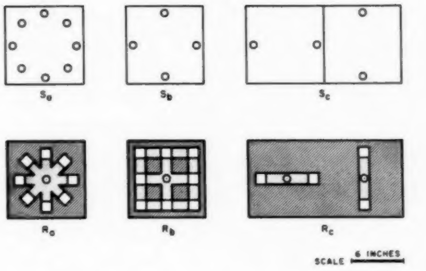
HUMAN COMMUNICATION CHANNELS

Shannon has established that every communication channel has a fixed rate at which it can transmit information without error. Any attempt to transmit information at a greater rate through the channel must fail. The information handling capacity of the human communication channel has been tested by numerous tasks and found to give consistent results[4]. The fastest human information rates were attained in reading aloud tests of random words[5]. These rates were computed to be 42 bits per second. Using entirely different techniques, G. C. Sziklai found that visual perception was limited to an information rate of 40 bits per second.[6] On tasks that called for perception rates of 60 bits per second, the operators consistently failed. Quastler[7] points out that people cannot respond more than nine times per second, or not over five responses per second when discrimination is required. A second limit exists because people cannot distinguish rapidly among more than 32 equiprobable alternatives without becoming confused. For arm-finger movements such as those of a skilled typist or pianist, Quastler concludes that 25 bits per second is the practical upper limit. Experiments by Fitts[8] point to 10 to 12 bits as a consistent upper figure for arm movements alone.



COMPLETE COMMUNICATION SYSTEM BLOCK DIAGRAM

Fig. 2



THREE STIMULUS PANELS (S_a, S_b, AND S_c) AND THREE RESPONSE PANELS (R_a, R_b, AND R_c). THE OPERATORS HELD A METAL STYLUS ON THE CIRCULAR BUTTON IN THE CENTER OF THE RESPONSE PANEL.

Fig. 3

PRACTICAL APPLICATIONS

The I. E. applications of Information Theory will range from studies of a complete industrial organization down to the synthesis of individual work stations. Useful applications will further vary from the quantitative to those cases where even a qualitative analysis will prove valuable.

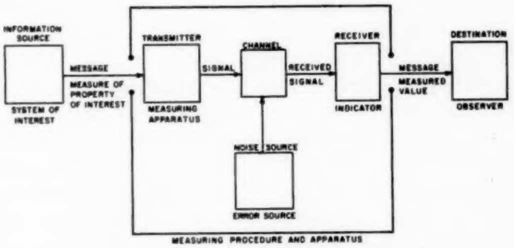
The author, in a previous article[4], has described a series of experiments by Paul Fitts[8] in which the information capacity of the human eye-mind-arm motor system was found to average 10 to 12 bits per second. The information rate of the eye-mind-arm channel for four different tasks in each of which the physical parameters were widely moved was found to be very consistent. The results can only lead one to believe that Information Theory will be used as a tool for Time and Motion synthesis. In fact, we understand that Information Theory has been used to design finger-operated keyboards such as that of a typewriter.

As an interesting sidelight on Fitt's work, the author established that the human brain is organized to perform multiple, disassociated tasks without loss of production if at least one task is completely repetitive, and if the motor channels involved for the tasks are separate. In checking the results of Fitts' repetitive taping experiment which involved the mind-eye-arm, the operators were found to be able to perform arithmetic problems involving the ear-mind-mouth channel with no loss of taping information.

Information Theory has been applied by Fitts and Seegar[9] and Fitts and Deininger[10] to the problem of the spatial characteristics of stimulus and response codes. There are numerous situations in which an operator waits for a stimulus, often visual, upon whose receipt he performs the task called for in the stimulus. The above investigators postulated that information would be transferred in a measure dependent upon the compatibility of the ensemble of stimulus and response characteristics. Compatibility effects were conceived as resulting from information transformation processes (encoding and/or decoding) that intervenes between receptor and effector activity. The rate of information processing is assumed to be maximum when these recoding processes are at a minimum. A series of experiments were devised in which it was possible to measure the rate of information transfer. A typical experiment is that of Fig. 3 in which the S's represent light panels and the R's the response panel manipulated by the operators. In S_a, only one light would be lit at a time to give eight possible position signals. In S_b and S_c either one light or two adjacent lights could be lit to again give eight possible positions. Each signal then corresponded to $\log_2 8 = 3$ binary bits. Tests were conducted using each of the S panels with each of the R panels in turn.

It was found that the rate at which a perceptual motor system can process information is a function, not so much of the characteristics of a particular set of stimuli, or of a particular set of responses, but rather of the degree to which the sets of stimuli and responses form a congruent match. With two-dimensional spatial coding, the rate of information transfer increase over other codes such as random or one-dimensional spatial, varied from 1.8 bits per second (corresponding to a choice of one in four equally likely alternatives) to 7.3 bits per second (corresponding to a choice of one in 160 alternatives per second).

Accurate communication is a product of channel capacity and code matching. Although there are many situations in which Information Theory will supply quantitative results, there are many more where it can act as a qualitative guide or a set of organizational rules. These rules, if understood and properly applied, will lead to more efficient industrial transmission of information. Of course, when some value is claimed for the qualitative solution of industrial problems with the aid of Information Theory, the counterclaim can often justifiably be made that an experienced manager would have arrived at the same or comparable results without it. However, Information Theory does give an excellent insight into the fundamental operation and limitations of a communication system and further defines those steps that can be taken to correct a malfunctioning system.



THE ANALOGY BETWEEN COMMUNICATION AND MEASUREMENT

Fig. 4

An interesting application of the concepts of Information Theory occurred recently when the manager of a substantial manufacturing operation realized that he was being overwhelmed by the flood of paperwork across his desk. Despite the efforts of an efficient secretary, he was unable to keep up with the decisions required of him. The staff consultant who was given the task of organizing the information flow to the executive decided to apply I. T. rules to the situation. The manager stated that the primary function of his position was to make decisions regarding the allocation of men and resources to meet the requirements of the division. (These requirements were brought to him in the reports of his subordinates.)

In studying the contents of the paper flow across the desk of the executive, the consultant shortly realized that the signal to noise ratio of the letters and reports was low. It was further obvious that a more efficient coding procedure was required. It was also apparent that the executive had the channel capacity (experience, ability, and time) to produce the required decisions. The papers to be handled were found to fall into two general classifications: (1) reports on work in progress, and (2) statements of problems requiring an ultimate decision.

To better utilize the executive's capacity, a simple coding procedure was put into effect. Each letter was classified into either a report, or a request for a decision. Those communiques which were merely information feedback on existing projects were requested to append a short statement on the progress that had been anticipated.

Reports involving problems were now required to clearly state the alternative decisions available, the recommended solution, and the manpower and resources required to effect this solution. Problems were not to be presented without a recommendation of a solution. If this were not possible, then it was mandatory that an outline of the steps necessary to generate an answer be submitted.

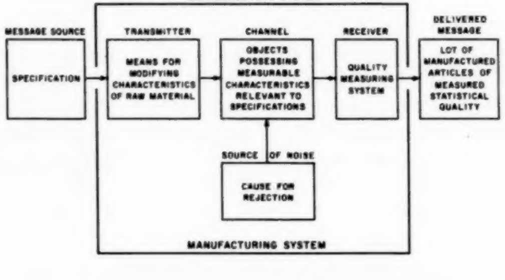
From the standpoint of I. T. the logic of the above procedure is, of course, rather elementary. The executive had some finite channel capacity and could transmit information accurately at a corresponding maximum rate. The amount of information involved in each decision is based upon the number of alternatives available. A decision involving a large number of alternatives would, therefore, require more time to clear a fixed capacity channel than a decision with few alternatives. By submitting problems with a proposed solution, including the costs, the executive's decision time was drastically reduced as he now knew all the alternatives and no longer had to consider an array of psuedo choices. Furthermore, his information transmitting task was still further reduced, for now he had only to decide to grant or withhold the appropriation in light of the soundness of the recommendation. The amount of information connected with each decision had been materially reduced, allowing a corresponding directly proportional increase in the rate at which he could reach decisions.

INDUSTRIAL SYSTEM APPLICATIONS

As long as the industrial organization is viewed as a communication system or an analogue thereof, its behavior can be analyzed and understood in the light of I. T. As was mentioned earlier, I. T. and statistical mechanics are intimately related. In statistical mechanics, entropy is a measure of ignorance or system disorganization. Since information is the negative of entropy, it has been called negentropy. Organization being the negative of disorganization can be considered to have the same form as information or again, a negentropy.

This analogy has been used to define organization and to give value to the amount of organization found in a system.[11] An organization can be assumed to be a set of interacting components or elements. Each active element (as distinguished from a passive structural component) considered by itself, will have its own associated set of alternatives. An entropy can be determined for each set of alternatives. If the elements did not interact, i.e., there were no cross constraints, then the system entropy would be a maximum and would equal the sums of the individual entropy. The organization would also be zero. If, however, the cross constraints between elements are great enough that only one choice becomes possible out of each set of alternatives, then the entropy is zero and the organization is a maximum. The amount of organization of a system then becomes the reduction from the maximum (sum of individual entropy) caused by the constraints, orders, procedures, instructions, etc., which restrict the choices available.

If entropies can be determined for the input and output ensembles of a given function, then the entropy of the function can be calculated. With this information, the system capacity, redundancy, and noise can be considered also.


COMMUNICATION SYSTEM
MESSAGE SOURCE
SPECIFICATION
TRANSMITTER
MEANS FOR MODIFYING CHARACTERISTICS OF RAW MATERIAL
CHANNEL
OBJECTS POSSESSING MEASURABLE CHARACTERISTICS RELEVANT TO SPECIFICATIONS
RECEIVER
QUALITY MEASURING SYSTEM
DELIVERED MESSAGE
LOT OF MANUFACTURED ARTICLES OF MEASURED STATISTICAL QUALITY
SOURCE OF NOISE
CAUSE FOR REJECTION
MANUFACTURING SYSTEM

THE ANALOGY BETWEEN COMMUNICATION AND MANUFACTURING

Fig. 5

Since the basic problem of all engineering is that of statistical inference, it is not surprising that analogies could be drawn between the statistical theory of communications, statistical quality control, and theory of measurements.[12]

The analogy between communication and measurement is illustrated by Fig. 4. Measurement, of course, is only one part of the quality control problems. Once the characteristics of a manufactured lot has been determined, a decision must be reached for their further handling. At this point Information Theory must yield to Decision Theory.

The analogy between communication and manufacturing is shown in Fig. 5. The terms inside the block refer to parts of the manufacturing process, while those outside are from communications. Past specifications are analogous to the message source. The transformation or coding of the specifications from raw material to finished part is the function of the transmitter. Manufacturing error such as wear, variation in materials, etc., give rise to channel noise. Noise can arise not only in the transmitter but also in the receiver due to errors in quality measurement.

CONCLUSIONS

The application of Information Theory and the allied Decision Theory to subsections of the industrial organization is well assured. For the entire industrial complex or major portions thereof, the analogue between Communication and Organization appears quite clear. As a conceptual model spelling out the rules and boundaries for the industrial system, the Theory has proven its worth. The extent to which quantitative analyses can be made will depend upon our abilities to recognize the alternative action possibilities which are available to each component of the system and to apply the appropriate values to them.

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APPENDIX

The Mathematical Theory of Communication[1]

The "why" of a theory of communication lies in the fact that the key problem of communication is one of statistical inference. In any system the message received is never a mathematically exact replica of the original transmission. In transmission the message will be subjected to random unpredictable perturbations commonly called "noise." The recipient of the message must apply statistical inference in attempting to extract the original message. Since all communication systems have some error potential, they are best described in the mathematics of statistical inference. As the "what" of communication theory is presented, the statistical nature of each element will be discussed.

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[1] As developed largely by Claude Shannon for mechanical communication systems and with concepts from Shannon and Weaver [13], Sanford Goldman [14], Brockway McMillan [15], and Liefer and Schriber [16].

The basic elements of a mechanical communication system are given in Fig. 1. The information source is the device, person, persons, etc., which in order to produce a desired change in the state of the destination, selects a desired message from a set of possible messages. The transmitter changes the message into a signal form which can be conveniently transmitted by the channel. We say that the transmitter encodes the message for transmission. The channel is the machine over which the signals representing the messages are transmitted to the receiver. The receiver decodes the signals into the message normally in a form meaningful to the destination. Noise is said to be any additions to—or distortions of—the original message. It is obvious that noise may take many forms. However, it is essentially any deviation from the original source intent and consequently noise might well be called error.

The block diagram of the mechanical communication system can be readily illustrated by a great number of physical situations. Since Shannon's work was sponsored by the Bell System, the names given the elements of the block diagram are fully descriptive of the situation of telephonic communication between two individuals. In this case at least, the concept of noise is easily related to one's personal experience. Again note that the communication engineer considers any change from the original as noise. It is the problem of grappling quantitatively with this random statistical phenomena of noise or error that has largely resulted in modern communication theory. With the recognition of noise the extent of the system elements task is further clarified. The receiver or decoding device must not only decode the original noisy signal, but it must also infer what the original signal really was.

Along with the noise that nature and man introduce into his communication channel, the engineer must concern himself with the additional all important statistical problem of bulk or volume of channel message traffic. The message bulk will be intimately related to the encoding process. One can easily verify experimentally that a long sample of English text can be readily restored to its original form even if half its letters or all of its vowels are deleted. Since in English all letters do not occur with equal probability, i.e., the letter "u" always follows the letter "q", and because of the unique meaning inherent in a long passage, there exist strong statistical connections extending over stretches of message. When a channel transmits English messages, its true information content is reduced because part of the message is devoted to telling us something we already know—the probability structure of the English language. All that is really needed is enough key data to allow a unique restoration of the original message. All other material would be redundant and a waste of channel capacity.

The latter part of the above sentence is not entirely true, however, for redundancy and noise interact. In a noisy channel where some of the message will probably be received in error, redundancy can be effectively used to reduce the final message error to any desired fraction. A common example of the manner in which the final decoder uses redundancy can be seen in the ease with which we normally perceive the correct message even in badly misspelled telegrams.

Shannon has posed and answered four questions about the general communication problem:[13]

1. How to measure amount of information and rate of information production in a manner which will take into account the probability structure of the message?
2. How to measure communication channel "capacity"? How many information units per second can be sent through a channel with a given signal power and a specified noise?
3. What are the characteristics of an efficient encoding process? With maximum encoding efficiency, at what rate can a channel convey information?
4. What are the general characteristics of noise and their effect on final message accuracy? How are the undesirable effects of noise minimized?

INFORMATION

In the following section while we are concerned only with the mechanical aspects of communication, information is not to be confused with meaning. One's initial contact with information in communication theory usually seems strange, for here information relates not to what you say, but to what you could say. Information is a measure of one's freedom of choice when one selects a message. If there were only one message that could be sent, the information would be zero as there would be no choice and no point in sending the message.

It has been found that information may be conveniently expressed in binary code or in other words, measured in terms of $\log_2$. For example, if one had 16 alternate messages from which he is equally free to choose, then $16 = 2^4$ and $\log_2 16 = 4$. This means that the situation and its particular message could be characterized by 4 "bits" of information from a binary coding system.

If a situation is highly organized, it is not characterized by a large degree of randomness or choice—

that is to say, that the information is low. Maximum choice or information for a given set of symbols will occur when the probabilities of occurrence of each symbol are equal.

Relative information for a given situation is defined as the ratio of the actual information (freedom of choice) to the maximum possible information for the same set of symbols. Redundancy is defined

$$\text{Redundancy} = 1 \text{ minus relative information} \qquad \text{Eq. (1)}$$

Redundancy then is the fraction of the message that is determined not by the choice of the sender, but rather by the statistical rules governing the use of the symbols in question. As was pointed out, this fraction of the message could be omitted in a noiseless situation and the message would still retain full information. English has been proven to be approximately 50% redundant.

Information H is mathematically expressed for the case of interdependent symbols whose probabilities of choice are $P_1, P_2 \ldots P_n$ by the equation

$$H = -\sum_{i} P_i \log_2 P_i \qquad \text{Eq. (2)}$$[2]

The minus sign only appears since P_i is usually less than one and H is taken as a positive quantity. If the probability of any symbol is unity, (symbol is certain to appear each time) $\log 1 = 0$ and the information is zero since only one symbol will always be transmitted. The units of H are bits per symbol.

Channel Capacity is defined in terms of the amount of information correctly transmitted per unit of time. Bits per second is the common unit. For example, a teletype channel could have a source that may freely choose from among 2^s symbols. Each symbol chosen then represents $\log_2 2^s = S$ bits of information. If the channel is mechanically capable of transmitting n symbols per second, then the capacity C of the channel would by definition be "ns" bits per second.

At this time we have defined information H in terms of bits per symbol. Information can also be rated in bits per second, in which the symbol H′ will be used. Without stating how we would determine the capacity, C, of a real channel, C has been defined in bits per second. With this rather elementary background the fundamental theorem of communication can be stated in all of its simplicity.

FUNDAMENTAL THEOREM OF COMMUNICATION

> "By proper coding procedures it is always possible to transmit symbols over a channel of capacity C, when fed from an information source of H bits per symbol at an average rate of nearly C/H symbols per second with zero error. However, no matter how clever the coding, the errorless transmission cannot exceed C/H."

The fundamental theorem can be stated another way. If the information source generates at a rate of H′ bits per second and feeds a channel of capacity C then errorless transmission can be approached if $C > H'$.

Information has been defined in terms of the freedom of choice in selecting a message. The greater the freedom, the greater the information, and the greater the uncertainty that the next message to be received will be some particular one. Noise causes the received signal to exhibit greater uncertainty or more apparent information than the transmitted signal. Noise therefore, is undesirable uncertainty or information which tends to confuse the decoder and cause errors. The powerful fundamental theorem states rather simply, however, that no matter how much noise is present, a coding method will exist that shall allow errorless transmission at a rate H′ which shall approach C the channel capacity. The statement of errorless transmission in the face of error producing noise is provocative. The only possible joker in the erstwhile simple statement might lie in the still unexplained derivation of C. (It so happens that C will be dependent upon the amount of noise present in the channel as will be subsequently shown.)

By illustrating the fundamental theorem with an example, it is possible to tie together the implications of noise, channel capacity, rate of information transmission, redundancy, transmission accuracy, the coding problem, and coding time. Consider the following elementary situation: A channel is capable of mechanically transmitting 100 numbers per second. However, the noise in the channel is great enough to insure that one (and only one) number out of each 100 transmitted is received in error. If this is an intolerable accuracy, we immediately look for some means of improving the transmission accuracy through this noisy channel—assuming we have no control over the channel and its error producing rate. The first and most obvious approach would be to catch the errors by introducing message redundancy into the communication. If each number transmitted were repeated before the next number were transmitted, any number transmitted in error would immediately show up as it would not match its preceding (or following mate). Thus by introducing 50% redundancy into one's message, we could immediately spot any error when the second number of the pair was received. This simple error detecting redundancy has the advantage of speed. It has the disadvantage of a 50% reduction in original number transmitting capacity, plus the inability to tell which of the unmatched pair is correct.

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[2] This form is similar to the defining equation for entropy in statistical mechanics. The term entropy has been adopted in classical information theory for the measure of uncertainty or information. Thus information theory is linked to the thermodynamics of Boltzman and Gibbs with the result that the mathematical methods of statistical mechanics form a guide for information theory development.

By transmitting each number three times, 66.6% redundant, the transmission can be made 100% accurate. However, the useful capacity of the system would now be only 33 numbers per second. The fundamental theorem though would lead us to expect much greater capacities for the system.

Let us try a slightly more sophisticated coding scheme with controlled redundancy. Suppose the numbers were transmitted in the sequence indicated in the following array:

$$\begin{array}{ccccccc}
a_{11} & a_{12} & a_{13} & T_{R_1} & & T_{R_1} & = a_{11} + a_{12} + a_{13} \\
a_{21} & a_{22} & a_{23} & T_{R_2} & & & \\
a_{31} & a_{32} & a_{33} & T_{R_3} & & & \\
T_{C_1} & T_{C_2} & T_{C_3} & & & T_{C_1} & = a_{11} + a_{21} + a_{31}
\end{array}$$

Where the a's are the original transmissions numbers and the T's are the controlled redundancy with T_R's equalling the sums of the rows and T_C's equalling the sums of the individual columns. For every 15 numbers transmitted, 6 are redundant for a redundancy of 40%. The code is self checking. An error in any one single number in the array can be found and corrected by the time T_{C_3} is received. Now if a 9 x 9 array were used instead of a 3 x 3, 81 useful numbers would be transmitted along with 18 redundant check figures. In this case the redundancy is only 18/99 = 18%.

The useful error-free transmission capacity has been increased to 81.0 number per seconds, but it is now necessary to wait for the transmission of up to 99 symbols in order to read the complete message, i.e., find and correct the error that must be present in every 100 numbers transmitted.

The heuristic proof embodied in our example bears out the fundamental theorem. By clever encoding we are able to use controlled redundancy to cause the error-free transmission rate of the system to approach the capacity of the channel. However, this increase in rate is not obtained without sacrifice, for the waiting time for message decoding (correction) increases rapidly as the transmission rate approaches its theoretical error-free maximum.

The ultimate error-free capacity of a noisy channel has been developed by Shannon for the transmission of both discrete and continuous symbols.

Capacity, C, of a discrete channel

$$C = \text{Max}\,[H'(y) - H'_x(y)] \qquad \text{Eq. (3)}$$

$H'(y)$—Total information including noise in received signal

$H'_x(y)$—Information (uncertainty) contributed to received signal by noise.

The maximum is with respect to all possible information sources used as input to the channel. For a noiseless channel, $H'_x(z) = 0$. Note again that the Fundamental Theorem says that for $H' > C$, the minimum error regardless of coding cannot be less than $H' - C$. Equation (3) lends itself to an experimental determination of C. Over an extended period of time, a record can be kept of the messages sent and the results achieved (messages received). At a later time a symbol by symbol comparison can be made and the probability of each received signal reevaluated and averaged. Where the received symbol coincides with the message symbol, the probability is one and information is zero. $H_x(y)$, the uncertainty of the received signals will be left. Shannon and Weaver offer further examples to illustrate the idea of capacity of a discrete noisy channel.[13]

The Industrial Engineer will undoubtedly apply the discrete channel theory to his production line problems, where he usually deals with discrete objects. However, there will be many occasions where the continuous messages such as the speaking voice will be used. The continuous signal, maximum capacity theorem is especially important for the light it throws on the relations between capacity, signal strength, and noise magnitude.

Continuous Signal Maximum Capacity Theorem:

$$C = W \log_2 \frac{P + N}{N} \text{ bits/sec.} \qquad \text{Eq. (4)}$$

C—Maximum capacity of channel

W—Frequency band width

P—Average signal power

N—Average noise power

The theorem indicates that with zero noise, the channel capacity becomes infinite. With efficient coding, information could then be transmitted at an infinite rate. Unfortunately, there are no truly quiet places on our earth. In every physically realizable system some noise will exist and C will be finite. The formula further indicates the well-known threshold concept, for as N approaches and exceeds P in magnitude:

$$\frac{P + N}{N} \rightarrow 1 \quad \text{and}$$

$$\text{Log}_2 \frac{P + N}{N} \rightarrow 0 \text{ or zero useful capacity.}$$

At this point we have completed our simplified presentation of the mathematics of communication as developed for mechanical systems. Without further expansion these mathematics could be used to describe and predict the ultimate performance of a humanistic-mechanistic industrial organization with the people replaced with perfect "man-machines". To account for the somewhat less ideal performance of the actual system, it is not necessary to modify the mathematics but only to recognize the additional error probabilities introduced by the human elements. This can be best accomplished by rapidly previewing the all important concept of channel capacity.

CHANNEL CAPACITY MEANINGS

A channel for transmitting code messages is a complete transmission system from an input location to an output location. The properties of the channel include the properties of the equipment used in the channel as well as the properties of the codes or languages used. Channel capacity can usually be specified at least three ways—in terms of code capacity, language capacity, and semantic capacity. The code capacity of a channel is determined by the fixed constraints which may be part of the code channel (for example, the dot-dash-space of electrical telegraphy) plus all the fixed constraints which may be present in the letter, word, and sentence codes of the language employed in the channel. The language capacity of a channel is obtained by superimposing the probability constraints of the language upon the fixed constraints of the code channel.

It can be proven that the language capacity of a channel will be less than its code capacity unless the probability of occurrence of a symbol is properly matched to the time duration of its code transmission. For example, the letter "e" being the most frequently employed in English would require the shortest code representation.

Language capacity as used herein is defined in terms of symbol by symbol (i.e., letter) transmission. In the mathematics of the mechanical transmission system, no attention is given to the meaning of the language symbols since meaning has no influence in the design of the system.

Semantic information and consequently semantic capacity can be defined by the basic information definition:

$$\text{Information received} = \log \left[\frac{\begin{array}{l}\text{Probability at the}\\ \text{receiver of the event}\\ \text{after the message}\\ \text{is received}\end{array}}{\begin{array}{l}\text{Probability at the}\\ \text{receiver of the event}\\ \text{before the message}\\ \text{is received}\end{array}} \right]$$

The numerator accounts for the noise in the system for in the noiseless case:

$$\text{Information received} = -\log \left[\begin{array}{l}\text{Probability at the}\\ \text{receiver of the event}\\ \text{before the message}\\ \text{is received}\end{array} \right]$$

Goldman[13] has discussed languages and semantic capacity in some detail. Weaver[14] points out that the introduction of the semantic problem causes a modification of the rather simple diagram of Figure 1 to recognize that a "semantic receiver" is interspersed between the mechanical receiver and the destination (Fig. 2). This semantic receiver performs a second decoding upon the message for it must match the statistical semantic characteristics of the message to statistical semantic capacities of the receivers. A semantic encoder exists between the information source and the transmitter to encode the intended meaning of the sender into symbols that the receiver can satisfactorily decode. In addition, a box must be introduced at the source entitled "semantic noise" to account for perturbations or distortions of the meaning not intended by the source, but, which effect the destination.

The semantic problem of the industrial situation is enormous. Undoubtedly a substantial portion of the difference between ideal and actual industrial performance can be traced to semantics. Adequate semantic channel capacity requires not only a common language, but a good vocabulary match, and an extensive sharing of cultures and experience. Here the meaning of the word semantics must be expanded to include not only the meaning of words, but the meaning of situations, and experience. The term semantics is used here to imply meaning, not just the dictionary meaning of the words transmitted, but meaning in terms of the original intent of the sender.

The dependence of channel capacity upon this expanded view of semantics is illustrated by the oft paraphrased story of a college professor who, lost in the mountains, asked a hillbilly for direction.[17] After the professor indicated he didn't know where Knudsen's Bridge, Gin Creek, or Ma Perkins' Hog Wallow were, the mountaineer gave up in disgust, saying "You can't tell nuthin' to nobody who don't know nuthin' to begin with!"

He was correct, for in terms of the mountaineer's message, the professor's semantic channel capacity was zero. They both spoke and understood the same language, but lacked the common object identification experiences which would have allowed them to communicate. Although the recognition of semantic mismatch between source and channel is frequently difficult, once the problem is recognized it is relatively simple to evaluate in terms of the mathematics of communication theory.

The introduction of the effects of the emotional characteristics of the human components represent the last adjustment that must be made to the mechanical communication system to faithfully simulate the industrial organization. Human emotional factors normally manifest themselves in the form of extraneous noise introduced between the semantic decoder and the destination (Fig. 2). Because of its psychological origin, we have chosen to call this noise "psychological noise." "Psychological noise" is intimately associated with what other writers have called the "effectiveness" problem.[15]

Psychological noise can be activated either by the message itself which may disturb the receiver, or by events outside the work place. Emotional factors can also cause additional semantic noise. A subordinate will frequently attempt to encode a message so as to both convey information and still please his superior—a situation usually not conducive to accurate communication. The effects of psychological noise are the same as those of mechanical noise. The useful channel capacity will decrease as the noise increases. While the system performance with varying amounts of psychological noise is readily understandable qualitatively, much experimental work must yet be performed before quantitative results are available. The extreme change in performance that can be observed in a normally efficient worker under severe emotional stress is not surprising when considering the channel capacity expression:

$$C = W \log \frac{P + N}{N} \qquad \text{Eq. (5)}$$

where P is the power of the message signal and N is the magnitude of the noise.

section 10

WORK SIMPLIFICATION

by **FLOYD W. SIMERSON**
Coordinator of Industrial Engineering
FACTORY MANAGEMENT DIVISION
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MR. SIMERSON has had a long and diversified career in many aspects on Industrial Engineering:

From 1936-41 he was an instructor in vocational subjects; from 1941-1944, an Industrial Engineer at Remington Rand; from 1947-1948, Supervisor of Standards at Union Metal Mfg. Co., and from 1948 to 1951, Chief Industrial Engineer at David Bradley Mfg. Works (Sears owned).

In 1951 Mr. Simerson became a staff member of the Factory Management Division of Sears. At present his duties are "to coordinate Industrial Engineering activities in our wholly owned and affiliated factories throughout the country. This includes Work Simplification, Standard Data and Work Measurement, Job Evaluation, as well as Human Engineering. However, most of my time is spent conducting Work Simplification Programs, not only in our factories, but as a public service, in several hospitals".

WORK SIMPLIFICATION

by Floyd W. Simerson

Coordinator of Industrial Engineering, Factory Management Division of Sears, Roebuck and Company

IN THIS ERA of keen competition, it is vital that industry and business alike, continually and conscientiously strive to make improvements in order to exist. Not only is it imperative that we improve our work methods, procedures and products, it is necessary to improve the morale of the entire organization as well. Constant improvement is our ultimate objective. To accomplish this Sears' factories chose the Work Simplification approach.

There are many concepts of a Work Simplification program. Some feel it is an efficiency drive, a speed-up program, a cost reduction scheme, a suggestion system, or an engineering experting program. However, a well organized and effective program is none of these. Work Simplification is a philosophy, a way of THINKING which is instilled in the entire organization.

Work Simplification is based on the concept that PEOPLE are the most important asset to the success of the organization. It implies that each person is on the alert for improvements in his activity. A Work Simplification Program provides the opportunity to participate as a team in the solution of each other's problems, thus giving dignity to each and every one. The whole basis of an effective program is PARTICIPATION not by just a few in the organization, but by many.

Once a program is started in a factory or an organization the first step is to select a coordinator for the office and one for the shop. These coordinators will be trained and developed to carry on the program. If the organization has an Industrial Engineering Department, the coordinator is selected from this group. He is chosen on the basis of his leadership ability, his technical know-how, and his ability to get along with people and get results. The coordinator and his associates, the Industrial Engineers, play a tremendous role in the success of the program. They are NEEDED as consultants when supervisors and employees ask for advice and guidance. In the Work Simplification Technique, it is the Industrial Engineer's obligation NOT to dominate, but to inspire. It is their responsibility to stimulate one's DESIRE to improve and to provide some encouragement along the way. It is up to the coordinator to continually foster and encourage such activity by providing an outlet for their ideas and inherent desires. This makes participants feel they are important members of the TEAM and that THEIR ideas are NEEDED. This improves morale. Participation in Work Simplification by the Industrial Engineering Department will elevate them to a higher position of respect and esteem as they are called on more frequently for advice and assistance. This makes the Industrial Engineering job more enjoyable and satisfying, as well as improving their morale and well being.

High morale in an organization is a very important business asset. It provides an essential competitive advantage that organizations can't afford to be without.

This task of continuously improving the operation and procedures in an organization is too much of a burden for the Industrial Engineering Department. They need help from other members of management, as well as the rank and file. It is through participation in a good Work Simplification Program that we are able to unleash this great untapped reservoir of ideas, latent in most people, and bring our ultimate objective to fruition.

Our program is patterned somewhat after that of Allan H. Mogensen's Lake Placid program. It consists of three phases:

Phase I—Management Indoctrination and Orientation of the Entire Organization

We conduct a series of nine 2 hour conferences for the top management staff. The philosophy of Work Simplification must start at the top and filter down through the entire organization if you are to reap its full benefits. Since workers tend to reflect the attitudes of management, it is vitally essential that top management enthusiastically participate and accept this program. For this reason, management must show the willingness to accept other peoples ideas and to give them a fair try. This is so important that if management does not honestly accept the program, there is little reason to go any further. When it does accept, it is time to forge ahead. In a nutshell, just how well top management accepts Work Simplification will depend on how others accept it. It is as simple as that.

Before starting the second phase, it is important to let the entire work force know what your objectives are and to solicit their cooperation. Usually representatives of labor are invited to participate in the first series of management conferences of the educational phase.

PHASE II—EDUCATIONAL PHASE

One or more pilot groups are generally selected from the middle management team for the first series of conferences. These groups will include representatives from all departments, including the office and engineering.

The educational phase consists of a series of thirteen two-hour conferences which we conduct with the company's coordinator assisting. For the series of conferences we furnish all the notes and supplemental materials.

The main objective of the pilot groups is to evaluate the method and material with the purpose of modifying it to fit their own organization. The program now becomes their program, developed by them rather than one that was imposed upon them. A steering committee is formed from the groups.

The next logical step in the educational phase is to expose other supervisors and key personnel to the modified program. These conferences are conducted by their own coordinator. As a rule, these have been more successful than the pilot series. The program format is continually improved to meet the needs as it is presented.

The key to the success of a Work Simplification Program is when the hourly paid employees are asked to participate. We encourage our factories to develop programs just for them.

The group is given a problem to solve through group participation. The familiar peg board operation is the most popular. In the hospitals, we used small test tubes in place of the pegs, thus changing the flavor. The problem is first given to one participant. He or she is asked to place the 30 pegs in the board and then remove them in the easiest way. The first person who tries it generally takes from 40 to 60 seconds to perform the task. Soon, however, others take over and as they team up and THINK collectively, they more than double their productivitiy. It is in the very first meeting that they discover for themselves what Work Simplification really is. After the solution of the problem, they are asked what they got out of the meeting, which becomes the basic PHILOSOPHY of Work Simplification. Usually, the following points can be summarized:

FUN TO PARTICIPATE IN GROUP ACTIVITIES

Most people enjoy taking part in group activity. It makes them feel important. They feel they are part of the organization—not just fixtures. If people are given the opportunity for self-expression, and receive some personal enjoyment and satisfaction from their job, their morale will be greatly improved. Remember—morale is the way people feel. If they feel good they will work with more enthusiasm and will accomplish more.

The Royal Bank of Canada Monthly Letter states, "High morale generates thinking and planning; it stimulates initiative and enterprise; it is the most important ingredient of efficiency, and only in its atmosphere are people inspired to seek the best."

To enjoy good human relations, we need to recognize the craving of people for RECOGNITION. They desire prestige. By encouraging participation, individuals develop a sense of importance. We attract them to us, arouse their interest in other people's ideas, stimulate their own thinking, and create a DESIRE in them to bring all ideas to fruition.

IT IS NATURAL FOR PEOPLE TO WANT TO IMPROVE

For the most part people want to improve but certain inhibitions are inherent. One of the main objectives of Work Simplification is to help remove psychological barriers from a person's mind, such as fear of loss of job, ridicule, and fear that their ideas will not work. Emotional blocks tend to undermine our own creativity by self discouragement. They become stumbling stones to our own progress. Participation in a good Work Simplification Program helps to remove these barriers and bring out the individual's desire to improve. This is accomplished by providing the opportunity to participate along with the appropriate "pat on the back" in recognition of good work. Also a good Work Simplification Program makes the participant feel his ideas are NEEDED.

WE LEARN FROM OTHERS

By organized group participation, we offer one of the most effective means of COMMUNICATING IDEAS in existence. Over 50% more ideas come from group thinking than by the solo method. One of our mottoes is "NO ONE OF US IS AS SMART AS ALL OF US." By taking part in a Work Simplification Program, one learns to recognize the ideas of others and discovers the real value of team work. It also develops an OPEN MINDED attitude by demonstrating willingness to give other people's ideas a fair try.

One of the major problems encountered is a lack of follow-up by management to implement the proposals for improvement that result from the program. Provisions should be made to expedite all worthwhile ideas before even starting a program. An effective Work Simplification Program should yield 80 to 90% acceptance of all proposals.

It is not wise to push too many people through the educational phase at one time. Some organizations place too much emphasis on the training phase and not enough on the application or follow-up phase. When this is done, the program becomes a glorified training program and will soon lose its momentum and fall by the wayside.

A good Work Simplification Program, if it is to be effective and yield continuous results, must have the mechanism for harnessing the enthusiasm and newly formed skills of the participants.

PHASE III—APPLICATION OR FOLLOW-UP

In most cases, as a series of conferences unfold, the graduates become members of a problem solving team. The team will generally consist of five members. An Industrial Engineer, as a member, is the technical advisor. Each Industrial Engineer will have at least one team and sometimes more. The team usually meets once a week to work on Work Simplification projects in both the office and the shop. When a graduate is assigned to a team, honest-to-goodness Work Simplification will begin in earnest for him. It becomes a part of his job. Various means are used to stimulate interest and to promote competition between the teams. There are many ways of creating and maintaining interest in Work Simplification. Work Simplification news items, trips to various events, or a visit to another company for the winning team, movies produced of the best projects, records of individual contributions being part of the individual's personnel record, etc., are just a few of the ways used to accomplish this.

We also visit the various companies at periodic times and conduct refresher courses and sometimes follow-up with programs on Conference Leadership and Brainstorming. Each coordinator is asked to send us a report on his progress each quarter. Any program of Work Simplification has to be "KEPT AWAKE" year after year to be really effective and to harvest the many benefits derived from it.

We also encourage individual contributions. Generally speaking, the company will hold each supervisor responsible for one improvement in his area each month. As a reward one of the supervisors who has contributed the most to Work Simplification will be selected to attend Mr. Mogensen's one week "recognition" conference, which is held annually for that purpose.

PHILOSOPHY OF WORK SIMPLIFICATION

Our program has been presented to several of our factories, one mail-order house, and as a public service, to several hospitals in the Chicago area. We have found wherever human intelligence and energy is required that Work Simplification techniques will apply. The common denominator between factory work, office work, or hospital activities, is PEOPLE. Work Simplification today is based on the philosophy that "people do best the things they enjoy." We dramatically illustrate this principle in our very first work shop.

YOU CAN SELL THEM

Robert E. M. Cowie says: "Unless a man is able to sell himself and his ideas, unless he has the power to convince others of the soundness of his convictions, he can never achieve his goal. He may have the best ideas in the world, he may have plans which would revolutionize entire industries or business establishments, but unless he can persuade others that his ideas are good, he will never get the chance to put them into effect. Stripped of nonessentials, all business activity is a sales battle and everyone in business must be a good salesman."

In recent years, efforts have been made to SELL people or to persuade them in the need to do a better job. Far better results have been obtained by this method. There is nothing wrong with good selling provided it's done in the right direction. It must be done honestly, factually, and with sincerity.

None of us likes to feel that he is being told to do something; we prefer to feel that we are acting on our own ideas or that we are thoughtfully agreeing with the ideas of someone else. This can be accomplished by good selling. When we convey an idea to someone else, it should be presented in such a way that he feels the idea is his own. The SELL THEM approach is much more acceptable to people because it recognizes the importance of human feelings.

YOU CAN CONSULT THEM

Many companies and organizations are experimenting with the Consultative Approach. They are finding that it really works. This Consultative Approach through participation is the very backbone of a good Work Simplification Program. Mogensen says: "The Consultative Approach requires two things; first, belief that your people have ideas that are worthwhile and that they have better ideas than you have. You must have the humility to consult your people about their ideas. You cannot believe that you have all the ideas, that you know all the answers, that you are the EXPERT. You cannot 'hoax' people by merely asking them for their ideas, you must be really humble." The Consultative Approach to Work Simplification is a philosophy. It is a state of mind in an organization which allows everyone to participate in finding EASIER and better ways of doing work, this increasing productivity and improving morale. The peg board solution is a good example of this approach. Using the Consultative Approach, we recognize the ability that a person has—thus making him feel important and an important member of the team.

DEFINITION

Most subjects have to be defined so we have a definition of Work Simplification. "Work Simplification is the organized application of COMMON

SENSE and a method of drawing on the know-how of all to find and apply EASIER ways of doing necessary work." In the hospitals it reads—"and apply easier ways of providing better patient care."

We are finding that genuine "Common Sense thinking is so uncommon." A program of Work Simplification will help motivate and encourage your people in using it. This application of common sense should be encouraged in all jobs wherever you have people engaged in activity regardless of what it is, whether it be sweeping a floor or typing a letter.

It Is Not What You Do But the Way That You Do It

Participation in either the peg board or tube rack problem demonstrates this very dramatically. Productivity depends on the METHOD we use. Generally speaking, the method that takes the longest time is the hardest, while the method that takes least time is the EASIEST. Work Simplification is a program designed to ELIMINATE WASTE of time, energy, and materials by placing direction markers on the road to finding an EASIER way. We use a motto: "WORK SMARTER—NOT HARDER—IT'S EASIER."

THERE IS ALWAYS AN EASIER WAY

The success of Work Simplification depends on how well this belief has been instilled in the people and how much of a DESIRE has been created to break loose from the usual "habit pattern." One has to religiously believe that there is always an easier way of doing any task. Just because a job was improved once, does not mean that it can't be improved again and again. One president of a large corporation said: "If I find an operation that has been done in my organization for six months, I feel it should be questioned. If I find that is has been done that same way for a year, I know for certain it is wrong." The only one "best way" of doing any task is to eliminate it completely. Mogensen says, "The largest obstacle to be overcome is the mental attitude of people who already believe that they are doing their job the one best way."

It Is Not What You Say But How You Say It

Unrestricted channels of communication are evident as the demonstration progresses. Everyone within the group has something to say. They communicate with each other as they progressively work out an EASIER method. One of the main objectives of Work Simplificatin is to motivate people by developing a sincere DESIRE to improve. Surely "you can't motivate successfully unless you communicate effectively."

It is our practice to take a motion picture of the group as they take part in the solution of the peg-board problem. It is then shown to them at the following meeting. They are asked to watch for evidence of the philosophy.

Participation in the solution of any problem gives a group the opportunity to LIVE, FEEL, and UNDERSTAND the philosophy of Work Simplification. In our program, we place major emphasis on the human side rather than the technical. It is a continuous program of motivation. Most important points are brought out by group participation. For instance, in explaining the three ways of getting results from people someone is TOLD to move his chair over to the side and sit down. We then ask the group how they felt about the technique that was used to get the job done. A discussion follows which reveals the three ways of getting results from people. These are:

TELL THEM

People in this country get resentful when they are TOLD to do something. Their blood pressure goes up. The "Tell Them" approach is a method of "pushing people" or driving them. Telling is not too effective except in transferring information from one person to another.

A consultant from the States was doing some work in India. One of his tasks was to develop some native statesmen into Industrial Engineers. During the early part of his training program he assigned a very important mission to one of his students. The student proceeded to follow instructions but somehow or other he really messed things up. The consultant called the student to his office and proceeded to reprimand him. In the process he said, "Why on earth didn't you use your common sense?" The Hindu pulled himself up to his full height and replied, "Common Sense, Sir, is God-Given—I have technical knowledge only."

HUMAN RELATIONS INVOLVED

Our second workshop is devoted entirely on the human relations side of Work Simplification. It is my belief that a well-rounded program will place a lot of emphasis on this all-important subject. General Wood, our retired Chairman of the Board, has often made this statement: "While systems are important, our main reliance must be placed in People rather than systems." In our Work Simplification Program, we are finding that "It's not the tools and techniques of Work Simplification that are important, but the PEOPLE."

The objectives of the second meeting are to motivate PEOPLE by creating a DESIRE to improve and to develop an open-minded attitude or the willingness to accept other people's ideas and give them a fair try.

We discuss the simple economics of this country. We find that many people have been led to "look upon freedom from want as a RIGHT rather than something that has to be earned." In the past, the thinking of people on how our wealth is produced and distributed has been very fuzzy. Many of the causes of labor unrest stem perhaps from the failure to understand a few economic facts of life on the part of both management and labor. There is an increasing demand for a higher standard of living among our people. They want better houses, cars, more fringe benefits, and more time to enjoy the benefits. Can our economy meet this demand? We try to impress upon participants that they have everything to gain and nothing to lose by finding ways and means of making their work EASIER, thus providing a richer, fuller life through higher productivity.

According to statisticians, if we in this country continue to increase productivity at the same rate we have for the past five years, we should, on an average, be enjoying twice the standard of living that we now have in just twenty years, and with more time to enjoy it. This means that we will have many new products and services as well as more of what we have today.

As far as Work Simplification and human relations are concerned, we must recognize the existence of two outstanding characteristics of human nature. Since the beginning of mankind, it has been natural for most people to resist change and to resent criticism. We expect all of our participants to have somewhat of a closed-mind attitude—in the beginning that is. So many of us so often feel that we are the only ones who have worthwhile ideas. Isn't it quite true that we take great pride in ourselves in trying to prove the other person wrong? Most ideas are 90% acceptable and only 10% unacceptable. The trouble is we are prone to recognize only the 10% bad and will make every attempt possible to kill the idea without trying to improve the bad 10% so the idea can be used. To deal with people requires the communication of many ideas rather than just the ideas of a few.

We hold a "Buzz" session using as a topic—"What are some of the killer phrases that your boss or fellow employees used to kill your ideas?" The group is split up into five or six participants each with about seven minutes to develop the list. The lists are then exchanged and read. They are usually quite humorous. Next the groups are asked to make a list of the killer phrases that THEY use to kill other people's ideas. The groups agree that this is not necessary as the list will be the same.

The traffic light symbol is used to show the open and closed mind. The red light is the STOP signal on the road to progress. It blocks other people's ideas and holds up progress. It is a "no admission" to other people's ideas. Our model traffic light spells out some of the more commonly used "killer phrases" such as: "Don't burden me with the facts"—"My mind is made up"—"It can't be done"—"We've tried it before"—"This is the best way"—"I'm perfectly satisfied"—"We've always done it this way"—"Leave well enough alone"—"I'm too busy now"—"It won't work I tell you"—"Why not change now?"—etc.

Man wants to stay in his little old RUT where he feels at home and secure. He feels he knows all about his job and is, therefore, reluctant to suggest changes. A good definition of a rut is "a grave with the ends knocked out." To be successful with Work Simplification you must first get your people receptive to change which can't be done when the red light is on. We must get our minds open "so other people's ideas can flow through and wipe out the cobwebs." We might say "the mind is like a parachute—it functions only when open."

In Work Simplification our groups agree that it is necessary to get the red light off and the green light on, in order to have progress. (The red light is turned off and the green light turned on.) This is the GO sign and our negative phrases now change to the following booster phrases: "Welcome; come in"—"I like your ideas"—"That is good thinking"—"Let's give it a fair try"—"There is always an easier way"—"To progress we must change"—"Why wait, let's go"—"We will make it work"—etc.

It's not easy to change people's attitudes and you can't expect it to happen overnight. It takes effort and a desire on their part to get and keep the mind open. Mr. Herbert F. Goodwin of M.I.T. says, "It is far better to invest time and effort into creating acceptance to change than in attempting to overcome resistance to it."

Three full educational phase workshops are devoted to the human side of Work Simplification. This creates a FRIENDLY and OPEN-MINDED atmosphere. We try to obtain maximum participation in each and every meeting and to encourage THINKING. This is the crux of our program. Only when people think, can there be progress. After all, "When most people stop to think, they stay parked."

THE ORGANIZED APPROACH

After creating the right atmosphere, we introduce the Organized Approach to Work Simplification which instinctively follows this pattern:

1. Select a job to improve.
2. Get the facts —make a chart.
3. Challenge every detail.
4. Consult all those concerned.
5. Develop an EASIER method.
6. Install the EASIER method.
7. Follow through.

The Tools and Techniques of Work Simplification

The first tool we introduce is the Flow Process Chart. This is part of step 2 "Get the facts—make a chart."

Everyone makes a chart in the meeting from a movie taken of an activity closely related to their particular field of endeavor. Generally the movie is taken in their own organization. Each person is given a work assignment. They are asked to select a job to improve and to make a chart of the present method. The coordinators and Industrial Engineers assist them on this assignment. The charts are all presented at the next meeting. The sixth workshop is devoted to step 3 "Challenge every detail."

In questioning the job, we use the common questioning pattern for each detail of the job.

WHAT is being done? WHY is it being done?
WHERE is it being done? WHY at this place?
WHEN is it being done? WHY at this time?
WHO does this and WHY this person?
HOW is it being done and WHY this way?

These questions are first asked of the job and then followed by each and every detail of the chart. Good, honest, open-minded answers will generally uncover several possibilities such as — Can we ELIMINATE, COMBINE, CHANGE THE SEQUENCE, PERSON, OR PLACE, and finally, can we IMPROVE.

The participant's work assignment is to question all the details of the job and list the possibilities for improvement.

The seventh workshop is devoted to observation and a study of the principles of Motion Economy. Each participant is given an assignment to make a flow chart of their improved method.

The eighth and ninth workshops are used to present and sell their proposed method to the group and to CONSULT with them for further ideas. Needless to say, we make use of most of the ideas sold to the group.

A simplified operator right and left-hand chart is introduced at the tenth workshop and the multiple-activity chart at the eleventh. Again a work assignment is given to select a job and make a chart appropriate for study. One of these charts will be used and presented at the twelfth workshop.

The final meeting of the educational phase is devoted to participants' effectiveness. They are shown how they can use the pattern of Work Simplification to improve their own job. The question is asked—"Are you too busy to be efficient?"

After completion of the educational phase we hold a formal graduation which is usually a recognition dinner. They now graduate INTO Work Simplification, and not out. They become a member of a problem-solving team and Work Simplification becomes part of their job. Management must allow time to each participant for his part in Work Simplification. As a rule, you can spend 20¢ and get $1.00 back on your investment through this program. However, it is my opinion that the improvement in the morale of the organization will be much more beneficial to the organization than the cost reduction.

BENEFITS

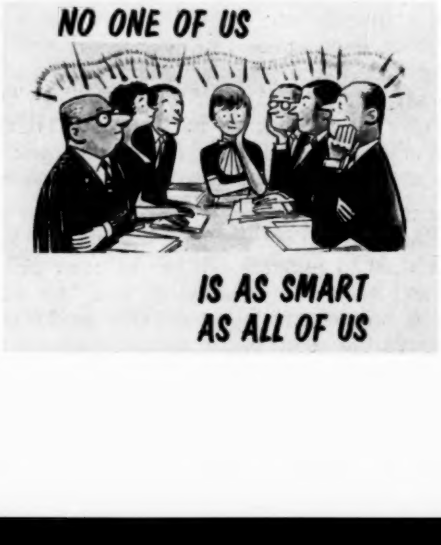
I mproved Human Relations and Morale
M inds of Personnel Opened
P roductivity Increased
R esistance to Change Decreased
O perator Gains in Personal Satisfaction
V iewpoints of Management Changed
E xpert Services More Readily Accepted
M ethods Improved—Cost Reduced
E mployee Gains In Status
N eeded Supervision Developed
T eamwork Greatly Improved

As you can see, these benefits spell one thing—"IMPROVEMENT."

Work Simplification is not a PANACEA for all managerial problems, nor is it a MIRACLE DRUG or a GIMMICK to cure ALL of our ills. However, in the proper hands, it is a proven invaluable tool to help solve many problems and is within the reach of ALL within the entire organization. It is a method of developing the CREATIVE GENIUS OF ALL INDIVIDUALS. As Vick Short says: "It can be compared with a bank account—You have to put some money in before you can draw on the account."

Participation in a good Work Simplification Program by the Industrial Engineering Department, can multiply their usefulness many times. It serves as a stepping stone to a higher management position. In the long run it will offer a richer, fuller life for all.

In reality, we can have only what we produce. To have more, we must produce more. To have the leisure to enjoy it, we must find ways and means to produce in less time, with less effort. THIS IS THE WAY TO PLENTY.



BASIC FUNDAMENTALS OF COMPUTERS

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BASIC FUNDAMENTALS OF COMPUTERS

by M. A. SHADER

Manager, Engineering and Sciences,
Industry Marketing, IBM Corporation

THE subject of automatic computing is certainly not novel. Indeed, it would be difficult to attend a professional engineering or scientific society meeting today without finding at least one group of sessions devoted to digital computers and their applications. The last decade has witnessed the emergence of the digital computer as a powerful tool in engineering and science, as well as in management. In the past five years we have seen nearly two thousand medium and large scale data processing systems take their place as regular members of the information handling and computing task forces of industry, government, business and education. Those of us closely associated with these developments believe that we have just scratched the surface and that the potential for the application of these powerful tools is virtually unlimited. There is no doubt in my mind that within the foreseeable future, say ten to fifteen years, the digital computer will be an intimate part of every engineer's repertoire.

It is my pleasant task this afternoon to review the fundamentals of computers and then to discuss briefly a few typical applications which may be of particular interest in the Industrial Engineering profession. Because the same digital computer may be used effectively in essentially all areas by means of different programs, I shall not devote any time to analog computers other than to remark that they must in general be considered as special machines designed for the solution of relatively specialized problems, often with remarkable efficiency.

The modern digital computer may be characterized as a device for processing and transforming information. Inherent in this notion is the concept that all information or data can be represented as a series of discrete bits or pulses. The representation of data in this fashion is quite natural since most electronic elements have two stable states. These bits of information may be assembled in a variety of codes with the result that these bits may be stored directly or converted into electronic pulses, and thus processed through an electrical network which will transform these pulses for the purpose of computation or control.

In order to carry out this processing of data the modern computer may be considered as the composition of five logical blocks. These are:

1. Input
2. Output
3. Storage
4. Arithmetic
5. Control

A discussion of the function of each of these logical blocks will both review the operation of the modern computer as well as highlight some of the differences among these machines.

The heart of the modern digital computer is its central storage system. It is here that all of the information necessary for the calculation to be performed must be stored. In general this information is composed of two parts—the data to be processed, and the statement of the problem in computer language. This statement of the problem in computer language is composed of a series of instructions and is generally referred to as the program. Thus both data and program are located in the central storage system or high speed storage unit.

From a technological point of view, the development of modern computers has been to a large measure the development of storage. The first popular storage devices were electromechanical relays and the field has progressed through vacuum tubes, mercury-delay lines, cathode-ray tubes, magnetic drums, magnetic-disk files, and magnetic cores. Machines are operating today in which each of these techniques is the principal means of storage. These storage devices or memories are usually subdivided into words. A word is usually the information equivalent to ten decimal digits. These memories may be classified according to capacity and speed, and I should like to give a few examples to illustrate typical values. A typical medium sized drum machine may have a capacity of 2,000 ten digit words with an average recall time or access time of 2.4 milliseconds. A typical large scale core machine may have a capacity of 32,000 ten digit words with an access time of 2.4 microseconds. Magnetic-disk files are capable of storing five or ten million ten digit words with access times in the hundreds of milliseconds. Technological improvements have made possible significant improvements in these speeds and capacities. Machines will appear on the market with ever improving characteristics.

In order to enter information into these computing systems, a variety of input devices have been and are being used. Among these are punch cards, magnetic tapes, punch paper tape, typewriters, and other keyboard systems. These same input devices may be used for output. In addition to the input devices just mentioned, printers, cathode-ray tubes, and plotters are widely used. These provide a great range of speeds and capacities with the determining factors being the requirements of the system and, of course, the economics.

The arithmetic and logical section of the modern digital computer performs the basic operations of addition, subtraction, multiplication, and division as well as those of comparison and logical choice. The ability to make comparisons and logical choice is central to the power of computing machines. In principle, any logical choice may be reduced to a combination of comparisons, and these may be performed by a machine as a by-product of subtraction: one choice being indicated by a negative result, and the other choice by a non-negative result. On today's machines these operations are performed in a variety of ways and with speeds varying from several hundred additions per second up to several million per second.

If we stopped at this point in our review of computers, and if we overlooked the particular speeds and capacities of the modern machines, we could have been describing the logical functioning of any of a variety of machines which have been described since Pascal conceived the basic ideas three hundred years ago. There have been many machines which could perform the arithmetic functions described so far, as well as read in numbers, store them, and exhibit results—the various models of desk calculators being prime examples. The modern digital computer was truly born when the late John von Neumann proposed the concept of the stored program for automatic control.

Under the stored program concept, the machine's operations are controlled by a set of instructions which are stored internally; that is, in the high speed storage unit. For example, in order to carry out the simple calculation:

$$B \times C - D = A$$

the following steps would be performed:

(1) The number B must be located in storage and brought into the arithmetic unit.

(2) The number C must be located, brought into the arithmetic unit and multiplied by the factor B.

(3) The number D must be located, brought into the arithmetic unit and subtracted from the previous result.

(4) The resulting answer A must be stored or read out of the system.

In order to keep track of data and instructions, the main memory of the modern computer is subdivided into locations each of which can store a word. This word, typically ten decimal digits and a sign, can either represent data or can represent an instruction. Each location in memory is assigned a number called its address. In this way, by specifying an address we are specifying a specific collection of digits, which is either a piece of data or an instruction. The usual instruction will contain two parts, often more. These two minimum parts are (a) an operation code specifying the particular operation to be performed and (b) an address which specifies the location of the factor to be operated on or worked with. Thus, in the example:

$$B \times C - D = A$$

the following set of instructions would be required:

(1) 10 (ADD) 1001
(2) 20 (MULT) 1002
(3) 15 (SUB) 1003
(4) 30 (STORE) 1004

For this example it has been assumed that the numbers B, C, D had been previously stored in locations 1001, 1002, and 1003, respectively. It had been further assumed that the result A was to be stored in location 1004 for future use. Moreover, it is assumed that the number 10 denotes addition, 20 denotes multiplication, etc., as indicated by the parentheses.

I have said that a typical instruction is 10 decimal digits in length. What use is made of the remaining four digits? In a particular machine these might be used to designate the location of the next instruction. That is, in the typical instruction there are two addresses; the first being used to locate the data and the second being used to locate the next instruction. In the example under consideration, if the instructions are stored in locations 1201, 1202, 1203, and 1204, the program would be as follows:

```
(1) 1201:  10   1001   1202
(2) 1202:  20   1002   1203
(3) 1203:  15   1003   1204
(4) 1204:  30   1004   xxxx,
```

where the last address in the fourth instruction would be specified when the next step has been decided upon. Thus, if the machine is provided with a starting instruction it can proceed, automatically, step by step, locating data, carrying out the numerical operation, locating the next instruction, and so on until the entire set of instructions has been executed.

I have dwelt on this particular aspect of machines —namely, the control by means of the stored program—because it is this characteristic which makes the modern machine so powerful. There are certainly other means of control. The most common other means is the use of pluggable wires inserted into a control panel. Here, storage would be used for data as before, but if it is desired to execute a series of steps, the particular configuration of these wires on the control panel would control the machine in its execution of these steps. The stored program has two major advantages over this approach: First, for lengthy programs, the sheer numbers of wires and the size of control panels become prohibitive. But the true significance of the stored program concept lies in the following notion: The machine, under control of the program, is designed to bring numbers from memory into the arithmetic unit, perform calculations on these numbers, and return the results of these calculations to the memory. Since the instructions reside in memory and have the same form as data, the machine can, under control of the program, bring instructions from memory into the arithmetic unit, perform calculations on these instructions, and thus change their meaning. That is, the machine can alter its own program in a pre-determined way as the results of conditions which arise during the course of the calculations. It is this ability to modify instructions during the course of the calculations which provides the modern stored program digital computer with its true power. This stored program control means that operation can be almost completely automatic and that programs can be written with widespread applicability.

There is an ancillary benefit to the stored program concept which is of particular value to people using the same computer systems. Since the program for carrying out a particular calculation is simply a set of numbers, these instructions may be punched on cards or written on tape and thus circulated widely among all users with similar requirements. In this way particular applications need be developed only once and, yet, can have widespread use almost immediately.

Now that there have been a number of years of experience in writing programs for these machines, many programs have been developed which reduce greatly the detailed requirements of the programming described above. Automatic programming systems exist which allow a machine to interpret mathematical statements and translate them directly into a machine oriented language. The engineer, faced with the problem just described, need only write the mathematical statement

$$A = B \times C - D$$

and the machine can take care of the rest.

Let us, then, summarize this brief review. The modern high speed digital computer is an information handling or data processing system composed of input and output units, high speed storage unit, and arithmetic unit all operating under the control of a program which is stored in memory in the same way as is data and which, thus, may be manipulated in the same way as numerical data.

I mentioned at the start of this talk that nearly two thousand of these machines have been built almost all of which are still in operation today. What are they being used for today, and what are they likely to be used for in the future?

The uses of machines to date fall into four principal categories: The greatest number of machines and the largest amount of time have been devoted to the record keeping functions of business, industry, and government. The mechanization of the various accounting records necessary to keep the world of commerce in motion has been the major consumer of the computing potential thus far developed. These record keeping tasks are often called file maintenance problems since they are principally concerned with updating large files of information based on daily, weekly, or some other periodic activity. Examples are payroll, policy records for an insurance company, etc. This type of application may be further characterized by the need for extensive data handling ability with a relatively smaller need for computing ability.

The second major use of computers and the oldest historically is for the class of application usually referred to as engineering and scientific computation. As an example of the use of computers in this area let us examine engineering design.

Engineering design is essentially a creative art. Since the computer cannot function without being given an explicit set of instructions, it is clear that a computer alone is intrinsically incapable of carrying forward a design problem. But the computer can be used to materially assist the engineer in detailing the consequences of proposed designs and thus can play a central role as an aid to design. For example, in the design of a structure, the engineer may be given certain load conditions and the problem to specify the dimensions of the various members of the structure in such a fashion that the cost, for example, will be minimized while all of the possible load conditions are taken into account. The role of the computer here is to carry out the computations for as many values of the variables as the design engineer chooses. In this way he can try literally hundreds of thousands of combinations of the variables and select the most desirable outcome. This type of use in a design problem is generally referred to as a "parameter study."

In engineering and scientific calculations, machines have also been used for simulation, for the computation of tables, for the prediction of experiments, for the compilation of statistical data, for quality control—to name just a few. This kind of calculation is, in general, characterized by higher computing and logical requirements and a lesser need for data handling characteristics.

The third general area of computer use is what may be called "control" or "real-time" application. An example of such use would be in the control of an industrial process. Here, readings from instruments would be transmitted automatically into a storage unit of the computer. Following this, suitable arithmetical and logical processing would be carried out, the results of which are then transmitted from the machine to actuators which control the process directly.

Another example which would fall into this category is the use of a computer for missile control. Data on the location of a missile is continually fed into the computer which computes the path of the missile and displays this path on an oscilloscope. As the missile continues along its path, tracking devices feed updated information into the computer, which translates this into a new path. In this way, the individual controlling the flight has full knowledge of the path the missile is following and can order changes in its path if it is steerable or can destroy it if it appears to be following a dangerous path.

The fourth, and last, general type of application I'd like to mention is the scheduling and control of industrial operations. This is the area of greatest interest to the Industrial Engineer and one which from the long range point of view has tremendous potential for industrial management. The successful application of the computer in this direction will draw heavily on the experience being gained in the three general classes of use that I have touched on so far.

An important part of many manufacturing processes is the job shop where parts can be made to order by a series of machining operations. The job shop is an array of machine tools such as lathes, milling machines, drills, etc., grouped according to function. When a part is to be made, a raw piece of metal must be taken from machine to machine in a specified sequence or routing, each machine performing a particular operation on the part, such as drilling a hole, lathing a certain dimension, etc. Since at any one time there are many parts in process in a shop, the allocation of time and machines for the machining of particular parts raise difficult questions. By constructing a mathematical model of the job shop, the computer may be used to simulate the operation of the job shop and provide several kinds of useful information.

In the typical job shop the flow of goods to be processed is scheduled according to a number of decision rules, which are either explicitly or implicitly formulated. Through the use of the simulator one may evaluate the impact of changes in these decision rules. Thus, scheduling procedures may be improved, or at least verified, by use of the simulator.

As one builds up experience with such a simulator, one may also evaluate the impact of additional machines or additional personnel in a given situation. Ultimately, through the use of appropriate input and output it may be possible to treat the job shop as a continuous process and actually control it by means of a digital computer which is "on-line" with the shop.

Another example worth noting is the widespread use of computers for so-called "management decision making games." A rather crude model of a highly simplified economy is constructed in which several teams producing a product compete in a simplified market-place. Each team essentially plays the role of the general management of the firm and decides how much of the product to produce, how much to charge for it, how much to spend for plant enlargement, research and development, marketing, and so on. These decisions are fed into the computer which relates the decisions of the competing firms to the hypothetical market and provides a statement to each team in which the effects of its decisions are listed. The teams thus learn how much of the market was captured, how much profit or loss was sustained, how much inventory is on hand, etc. Again decisions are made and the "game" proceeds. After a number of "years" the game is halted and one may analyze the play and performance.

I'm not trying to suggest by this example that businesses will be run by machines, but rather that the impact of various decision making processes may be examined if one has a sufficiently accurate model of the business system. One real study of this type which is underway today is a capital investment model for a large enterprise. The researchers are trying to develop a mathematical model of the behavior of the organization as a consequence of capital management. If successful, the model will enable management to assess the impact of allocating funds to plant as opposed to retail outlets, as opposed to warehouses, etc.

And to conclude this talk I should like to really get speculative and suggest that it may be possible to integrate a computer into the overall operation of an industrial complex. First, it can be used to design the process and plants necessary to carry out the operation. This is the engineering design application. Second, it can be used to schedule and control the operation. That is, raw material in the form of goods will be ordered, their flow through the manufacturing cycle will be controlled, and their distribution to warehouses or other customers will be regulated. This is the real time or control application. Third, the maintenance of records and financial controls will be performed on the computer. And last, the overall performance and allocation of resources will be augmented by this powerful tool.

It seems to me that for the Industrial Engineer, concerned as he is with management and control of the business system, the modern digital computer or data processing system is the natural tool. All of the applications I have described are being done successfully today in some areas. It is the Industrial Engineer's challenge to take these limited successes and exploit them in the areas which seem to beckon.

section 12

HUMANICS OF INDUSTRIAL ENGINEERING

by **JEROME BARNUM**
Director and President
JEROME BARNUM ASSOCIATES
SCARSDALE, NEW YORK

Since 1949, Mr. Barnum has held the position of Director and President of Jerome Barnum Associates which now consists of over a hundred professional consultants working out of the J.B.A. offices in the U.S.A., Canada, Mexico, South America, and Europe. This organization conceived the concept of "Directed Energy" in management and have brought this "way of life in private enterprise" to over 3200 companies and public service organizations in fifteen free-world countries.

Mr. Barnum is a lecturer at N.Y.U., the Wharton School, Westminster College, and the Technische Akadamie in the Ruhr, Germany. He serves a wide variety of blue chip clients in America and abroad, and currently is reorganizing every department of the Government of Nova Scotia.

HUMANICS OF INDUSTRIAL ENGINEERING

by Jerome Barnum

Jerome Barnum Associates, Inc.

THE great need in the free world today is *"research and invention in the realm of ideas in respect to the way men can work and think and dream together in a private enterprise society dedicated to the utilization of the resources of nature, and of human nature, for the betterment of the lot of man here on earth."*

The NEED
HOW?

There can be no sharp distinction between research and invention. However, invention is the word we attach to the specific result. Research, on the other hand, deals with the delving into the thousands of curious factors and avenues of inquiry that may lead to that result. Tonight, let us be researchers.

The basic fact of today is the staggering rate of change surrounding every facet of human life. Change presents challenge *and* opportunity.

The basic concern of this conference should be, I believe, the survival of free man of this earth. That question is by no means settled as of tonight. "Countdown Berlin" is but one manifestation of a polyglot problem of awesome proportions.

THIS
OR
THIS?
SLAVERY

In the long look of history, the success or failure of the Industrial Engineering profession may be decided as of today. We have the capacity to tip the balance in the verdict, "Has 20th Century America something vital and precious to be preserved, or is it simply a crude imitation of Athens or Rome? Is America on the threshold of a final and tragic decline?"

In the process of working in various parts of the world, I have not been able to escape forming some impressions. What Nehru called "The Tragic Paradox of Our Age" is not an American invention; but it might be subject to the melancholy judgment of being an American *lack of invention in the realm of ideas.*

USA
QUO VADIS?
ROME
ATHENS

More specifically, those of us who are Industrial Engineers, social psychologists, and management analysts must stand indicted for at least interim failure. We are like the German about whom the philosopher said "he performed each minute step with infinite accuracy as he swept on to the grand fallacy."

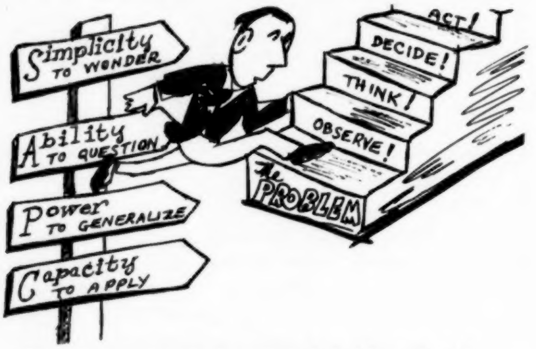
Industrial Engineers have many technical problems to face. But even a surface consideration of these matters leads inevitably to a wider and deeper range of thought. Unless we are wise, unless we develop sensitivity to the *total* picture, unless we discover clarity of vision (or at least are clear about the questions being posed to us), unless we tune in that clear small voice that forever whispers "quo vadis"—whither goest thou, then all may be lost in the confusion that muddles the world today.

I do not pretend to have the answers to these greatest of questions that have been presented to mankind. I can only say in sincerity and humility that I have dedicated my life to researching them and I am constantly thinking about these questions. That is what I am going to ask you to do . . . for if you will do this . . . think . . . then these problems will be solved and free man will survive.

If we are true inventors and researchers, let us not be dismayed in this undertaking if we frequently fail. An inventor is constantly failing. He may try, and fail, a thousands times; but if he succeeds once, he *has it made.* (Do we recognize this in our management and methods research?)

Let us also learn that we cannot look for the answers to the great problem of our age in the books. No matter what we are trying to do, if it is new we can find some book that will say it can't be done. We have only one inflexible rule in Jerome Barnum Associates: If we are truly working on a new approach or a new problem, stay away from bookshelves and committees in the beginning, as both will tell you we were nuts to start the project in the first place.

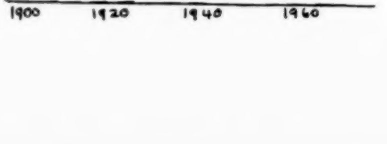
The first step is always to *define the problem.* After that you can study it and come up with some ideas as to how to proceed. Then you can tap your reference sources, your books and committees, if you have plenty of time—and find out what others thought about it. Basically, you are demonstrating the *simplicity to wonder,* the *ability to question,* the *power to generalize,* and the *capacity to apply.*



The problem needs more definition, but let us take a stab at it tonight; because even in taking a very long journey, the Chinese proverb tells us, it is necessary to take the first step first.

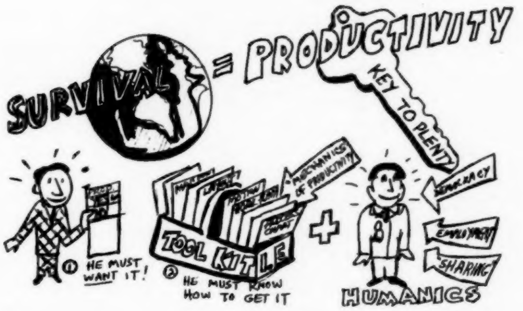
THE PROBLEM

In our lifetime amazing changes have occurred, and each of us who knows the world of the laboratory realizes that we are now on the preliminary threshold of the technological age. Man needs no longer to be the helpless victim of external forces. We approach a time when life can be good for all men. Yet, while man forges the conquest of his external circumstances, we witness the weird spectacle of the disintegration of the value system which could make it all worth while, the decay of the moral and spiritual fabric of man's existence, and the apathetic violin solo being rendered as the forces that would enslave man shove, and shoulder, and sneak, and squirm, and snake their way ever nearer, ever clearer, on the path of certain exhaustion of civilization itself.



Specifically:

1. The Western World can survive only if we achieve a constantly rising productivity rate, on a lot healthier platform than we have witnessed these past ten years. This is specifically our joint responsibility and *our job.* It is the task of management, engineers, scientists, and workers.
2. Productivity is the only key to plenty, so it is the sole source of the more abundant life we claim we want.
3. The essential, dramatic increases in productivity required in the free world cannot, and will not, come about until people really *want* them. Each of you know that the employee group that truly thirsts for higher productivity in America today is the rare, if not nonexistant, exception rather than the rule.
4. The Industrial Engineering profession has developed a tool kit—a set of analytical techniques—that can be used to increase the productivity of almost any operation, yet these basic hammers and pliers of the management trade are almost completely unknown to at least ninety percent of the members of management—foremen, supervisors, middle and top management—and unused by ninety-nine percent of our individual contributors, the non-supervisory employees.
5. Considering the foregoing four points, we must conclude there is much room for improvement in the "mechanics" of management, but that is only a small part of the job. The next series of conditions deal with the *"humanics"* of making it all worth while. It will not profit us to conquer the physical world if we in turn fail to conquer ourselves. Herein is Nehru's tragic paradox of the mental conflicts in this age of transition. The physical changes in the future will make all the material progress that has gone on up to now appear to be but a stumbling, bungling beginning. This, of course, presupposes that man will not allow science, which he has created, to turn around and destroy its creator, by being overwhelmed and annihilated in a nuclear war bursting the balloons of civilizations with the sudden pinpricks of ICBM's. Again, science advancing beyond our comprehension, and posing problems we have been incapable of understanding, much less solving, forces us to ask "quo vadis"—whither goes thou, and *What is the meaning of life?* We must also ask, "Productivity—to what end?"
6. Here in America we are a people dedicated to concepts of freedom and something we loosely call "democracy." Man spends most of his life, the largest number of hours each day by



far, in connection with his work. How much freedom and democracy do *your* workers have? Is this whole American value system good only after 5:30 p.m.? Can we expect man to live as a free, effectively-functioning, participating, democratic member of the human race between 5:30 p.m. and whatever time he goes to bed, and then become part of an authoritarian states (our businesses) all day long? I doubt it. *This question faces us* as humanity goes to the test. The old days of non-thinking acceptance or apathy do not appear to be adequate in this changing world. Living that has meaning and vitality is a continuous adjustment to changes and happenings. So is management. If things would only not change we wouldn't need managers! It is the lack of adjustment that creates conflicts as well as bankruptcies. Let us plan against spiritual, as well as financial, bankruptcy!

7. Unemployment, whether it is temporary, transitional, or "permanent" cannot be tolerated in an enlightened society. It is no good to tell the unemployed father of five or six children that employment "on the whole" is on the increase. *It is a very personal thing.* It is also a big, unsolved problem of our way of life. I fear I may infuriate many by mentioning one or two personal views on this subject:
   (a) From 1850 to 1950 productivity increased five-fold while hours worked per week dropped from 70 to 40. Have we now come to think there is something holy about the 40-hour week? I am sure it will be down to around 24 hours while some of us are still alive.
   (b) I believe that no company will ever achieve its true productivity potential without giving guarantees *in writing* that no one will ever lose employment as a result of thinking up new and better ways of doing the work.
   (c) I believe this problem is the most vulnerable point in the capitalist society and its early solution is essential to counter the talk in Communist circles of the contradictions of private enterprise. Unless it is solved, I am afraid the wake of disillusionment that could follow a major recession might become a vacuum into which the false faith of Communism and the disciplines of an authoritarian state might rush.
8. Man was not born to run your machine, or add your columns of cost figures, but to *live*. We are not only building products or rendering services, but more particularly *we are building a world*. Therefore, the people in our companies, where most of their lives are lived, have to encounter *"l'ambiance" for personal fulfillment*. Here is where energy and spirit overlap. Human beings need a minimum sense, at least, of being in charge of their own lives. Part of your job is to reconcile the forces of human destiny with the forces of efficiency. Rationalism, and the Foundations for "Economic Education" too often skid along the polished surface of this problem without ever becoming aware of its inner core. It is clear that in the final analysis it is the quality of humanics that counts. People are our most important asset; and we must subordinate every other consideration to the needs of man and how to meet them. Can this be done in a private enterprise economy, a private capitalism? I think it can. In fact, I believe it can be done in no other way.

Since we started talking from a viewpoint of research and invention in the realm of ideas, what can we do next? I said the problem needs further definition, so one thing we can do is go on defining it. In the meantime you might also shoot the next politician you hear uttering that glib bit about American "knowing how to sell soap but not knowing how to sell themselves." We must remember that marketing involves product-analysis as well as sales promotion techniques. When a soap doesn't sell we look at the soap itself, as well as the advertising.

Since none of us is ever smart enough to arrive directly at the final "right" answer to anything, we must think very hard, and we must study, *and* we must *create*. We have to work our way laboriously from experiment to experiment, and from test to test, until we finally come up with something that works. A lot of people are unwilling to do this. They would like to shortcut this tedious "nonsense." Unfortunately, the only people who have ever produced in the laboratory are the ones who never thought their education and their native intelligence were so great as to avoid the need for trying things out to see if they would work.

I want to devote most of my remaining time to relating to you some of the things that seem to be working for us. If the yardsticks for measuring success are to be increased productivity and enhanced human satisfaction, we would have to say these things *do work*.

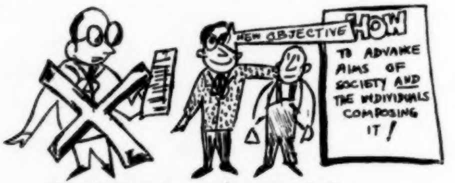
INVENTING AN IDEA

Now we come to the stage of *analyzing the problem*. Eventually our group found one method that works. I am sure there must be other methods. Improving our method will be a lifetime job. It is a matter of tedious and sometimes painful trial, test, and experiment; but we know of no other way. The answers are not in the books.

The answers we find seem extremely simple once they are worked out, but remember that "nothing is complete until everything possible has been taken away from it." We call this method "Directed Energy."

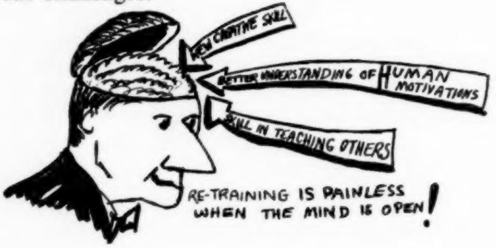
We couldn't have calculated these things. No one we know is smart enough to make such calculations, although we *think up* the things to try in our heads. Then we go through the primitive process of trying something out, learning as much as we can about its strengths and weaknesses, and trying something else. The "Directed Energy" approach is constantly changing although its basic philosophy has remained constant.

Our first step consisted of a reorientation of the management consultant and the staff Industrial Engineer. We rewrote our job descriptions and our company objectives. Now we have placed at the top of our responsibility list "the study of industrial life to discover ways of advancing the aims of society, *without* transcending the aims of the individual human beings composing it."

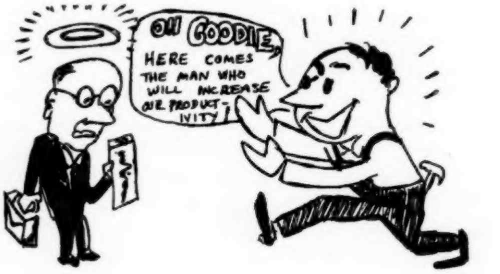

NEW OBJECTIVE
HOW
TO ADVANCE AIMS OF SOCIETY AND THE INDIVIDUALS COMPOSING IT!

THE INDUSTRIAL ENGINEER'S CHANGING ROLE

In order to equip ourselves for this task we set out to reeducate ourselves: to improve our inventive skills and attitudes, to learn more about man and his basic motivations, to even understand the questions posed by our times, and to learn to teach and to stimulate others into thinking about these great challenges.


NEW CREATIVE SKILL
BETTER UNDERSTANDING OF HUMAN MOTIVATIONS
SKILL IN TEACHING OTHERS
RE-TRAINING IS PAINLESS WHEN THE MIND IS OPEN!

We said to ourselves: "Productivity is the only benefactor our workers have in terms of reaching the higher standard of living everyone claims he wants. Therefore, when the Industrial Engineer appears on the scene with a new method there can be only one logical reaction: "Oh, goody, here comes the productivity man. His work will result in a higher standard of living and a more secure Western World for my children and their children's children. What lucky people we are to have him around." And we asked by a show of hands how many of our people are customarily greeted that way. Ask yourselves this same question, Mr. President; Mr. Industrial Engineer.


OH GOODIE, HERE COMES THE MAN WHO WILL INCREASE OUR PRODUCT-IVITY!

The conclusion had to be that people either were kidding themselves about wanting the better way of life, or else they really didn't believe that productivity was a good thing *for them*.

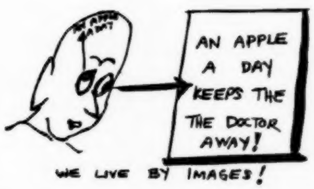
But weren't the "facts" clear, you may ask. We learned that no one, not even you engineers and scientists, live by "facts"—not one of us does. Rather, we live by images—stored up beliefs—and we act and behave as though these images, rather than the things they represent, are "truth." Let us try a little experiment to illustrate how it works.

Read this statement aloud:

AN APPLE
A DAY
KEEPS THE
THE DOCTOR
AWAY!

Editor's note: 95% of all engineers and executives tested have read the statement incorrectly. Mr. Barnum has used this experiment, and ones similar to it, in over 100 management training programs he has conducted in fifteen different countries.

The reason you read this simple statement incorrectly is that you have stored in your mind a statement that reads "An apple a day keeps the doctor away!"—and so compelling is this "image" that you have "read" it, instead of the statement you are looking at with your eyes.

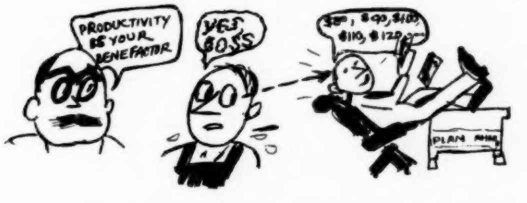


WE LIVE BY IMAGES!

We realized that if we wanted to change human behavior in an industrial environment, or anywhere else for that matter, we had to first change the image upon which it was based. Images are the result of our perception of experiences, knowledge, and sensations. We realized we would have to add new experiences, knowledge, and sensations to produce new images. *Then if we were lucky, we might get different reactions.*

In order to carry out this project we had to undertake a study of contemporary images, at all levels of industrial society, of "productivity." This study would fill a book, so I will concentrate on two aspects of this image tonight:

1. At the foreman and worker level the relationship management claims between personal advancement and increased productivity is regarded as a trick or gimmick. The factory worker, for example, may be able to see that his income has gone up 25% as productivity has increased a more or less comparable amount; but this same worker also knows a milkman, or plumber, or carpenter (whose productivity hasn't changed a single bit) whose income has gone up 25% or maybe even more, during the same period.



2. At all levels, including middle and upper management, there is fear of unemployment. Many will tell you, "Sure, productivity could be doubled next year—but half of us would be out of work. For the ones who remained there would be no real desire to share, on any fair basis, the fruits of the increased productivity. Productivity may be fine, in the long run; but we have to live in the short run."

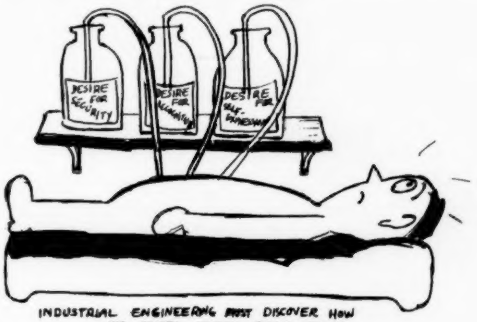
We believe this problem will only be solved when some modern counterpart of Henry Ford I duplicates his dramatic decision on the $5.00 day with a similar move in the realm of working hours; sharing the fruits of increased productivity, and protecting employment-continuity among the people who are affected by technological advancement.

It is a complex problem, and I don't pretend to have all the answers. I feel that some concerted broad-scale action is necessary; but until that comes along, we have found it is wise to give the necessary assurances, project by project. Because we are sincere about it we are believed. When you are believed you see the alchemy of new attitudes going to work and people start to say, "Now, maybe this isn't such a bad idea after all."

Now, let us go to the next point. When someone comes to believe that increased productivity is a good thing for him, in his own perception of what's good for him (as opposed to yours), do you automatically get acceptance and support? Of course not. The *way* a thing is done is just as important as *what* is done.

We studied fundamental motivations, and after clearing away all of the confusing semantics of the "head shrinkers", we talked a lot with people working in all kinds of jobs and came to the conclusion that we do the things we do to satisfy some rather simple hungers that all of us experience. They are like chemicals in our system, and we do things to satisfy them, and we do things to avoid having them taken away from us.

Some people call this "augmentation of need satisfaction", or the "diminution of need satisfaction". These hungers are for *security, recognition,* and *self-expression.* You can give them fancier terms, but this is what they boil down to.



INDUSTRIAL ENGINEERING MUST DISCOVER HOW TO MEET THESE BASIC NEEDS

Picture three bottles containing these ingredients on a shelf with tubes connecting them to your system. The "mix" you have may differ from mine, or from the fellow's sitting next to you, or from the little lady's at home; but *the ingredients are universal and unchanging.* The way you act and react depends on your "mix". The best way to have trouble is to ignore this basic chemistry of man. I am afraid that is what we do most of the time in Industrial Engineering. It is, likewise, the tragedy of top management thinking in the free world.

The law of intelligent action says you accept conditions as you find them, and then proceed to make them work out for the general advantage. One thing we have to learn to accept is basic human nature itself. Its been that way a long time and its going to be that way long after we're all dead and gone. St. Thomas Aquinas put it this way: "God grant us the serenity to accept the things we cannot change; courage to change the things we can; and wisdom to know the difference."

Since the basic nature of man is not going to change, our job in business becomes one of understanding it, and designing a way of working with it. In other words, the *thing that can* change is *business:* the way we deal with man in the industrial climate.

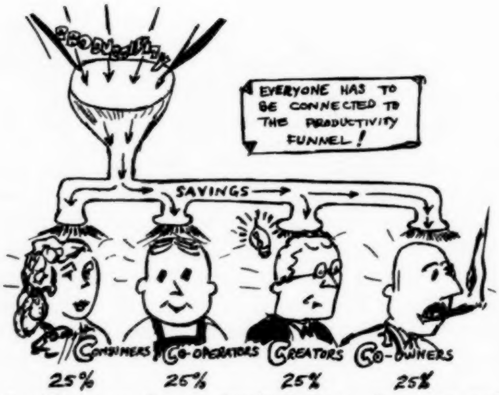
Our main job as Industrial Engineers is to find a way of doing our work in a manner that will meet the requirements of man's fundamental needs for security, recognition, and self-expression. Unless we succeed in doing this, we may "perform each minute detail of our work with infinite accuracy as we sweep on to the grand fallacy". Let us now have a look at the approach we have been using that has met with quite a bit of success.

THE DIRECTED ENERGY APPROACH

1. We sit down with the client and work out a set of policies everyone can live with to cover the basic questions of employment, unemployment and sharing the benefits of increased productivity. We limit our work to client companies who are willing to do this. Generally speaking, the sharing formula works out like this:

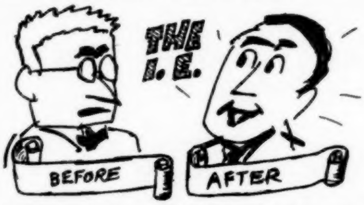
> 25% of the benefits to "Consumers" (the people who buy the product or service). This is done through price reduction, quality improvement, product upgrading, better services, and the like.
>
> 25% of the benefits to "Cooperators". (That's the term we use to describe everyone who works in the enterprise from the janitor to the president). Usually this money is put aside as a kitty out of which the wage increases can be paid.
>
> 25% of the benefits to "Creators". (That's what we call the people like yourselves who think up the good ideas that reduce the costs in the first place). Frequently, this is done through something like a suggestion plan, performance appraisal, plus research budgets to "keep up the good work".
>
> 25% of the benefits to the "Co-owners" (shareholders). They deserve something, too —but not *all!* Of course from their standpoint, sharing works out to be good business as well as good morals, since profits invariably go up.

This formula benefits everyone—and doesn't cost anyone a cent.



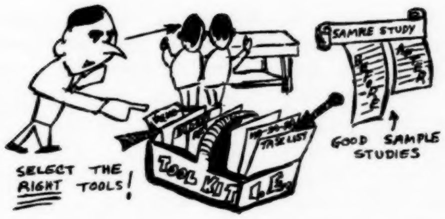
2. After we have checked into the economic soundness of the company's program for dealing with rising productivity, we endeavor to take a picture of the corporate image from the viewpoint of the people who work there. We, then, are in a position to get specific about the things that have to be done if the proper "climate" for the total program is to exist. We call this step the "basis diagnosis" and it includes an audit of the company's performance of meeting the human heeds for security, recognition, and self-expression. We always follow a policy of protecting employment as productivity rises. This is not as difficult as it first appears to be if there is sound advance planning.

3. Next we retrain our Industrial Engineers, systems men, organizational specialists, quality control, and personnel people: everyone who is expected to "service" a productivity program. Basically, this is a plan of training that is aimed at allowing the Industrial Engineer to "stop doing Industrial Engineering work and to start doing humanity's work." He learns how to re-orient himself into the kind of role occupied by a beloved teacher you once knew, instead of "the needle" on methods.



4. At this point we decide *which tools* of Industrial Engineering have the greatest "pay-out" prospects in each division of this company. This is done by evaluating the type of work each does, selecting the tools we ourselves, as management consultants, would use to improve their operations. As a result of this step, we can "prescribe" tools much as a doctor prescribes medicine. We work out some "sample" case applications.

5. Now we are ready for top management. We get the chief executives together. It may either be all of the officers and division heads, or this group plus the board of directors. We give them an


SAMPLE STUDY
BEFORE
AFTER
TASK LIST
TOOL KIT I.E.
GOOD SAMPLE STUDIES
SELECT THE RIGHT TOOLS!

appreciation session and have them take part in enough productivity demonstrations and problems to make sure they know what it is all about. Usually we take them away to some retreat atmosphere such as you will find in a hotel in the mountains, a spot in the Florida Keys, or (in rare cases) a glamour setting such as the Prado de las Americas in Acapulco, the Virgin Isle in St. Thomas, Sjusjoens in Norway, or the Hougenpot Castle on the Rhine. (We'll go to the French or Italian Riviera if necessary, and stop twisting my arm.) The point is: whatever is required to get the executive group away from the day-to-day realities of turning out work and into an atmosphere of inventive curiosity, we will do. This usually involves 24 hours of "sessions" spread over a three-day period.

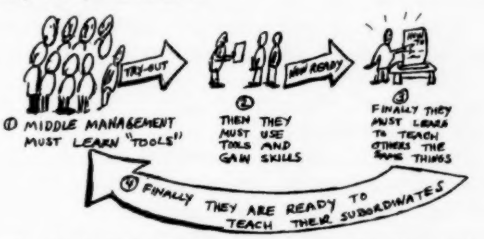
ANALYZE
EXECUTIVES MUST LEARN ALSO!

6. Next we "train trainers". This involves taking the members of middle management, superintendents, office managers, and other supervisors of supervisors, and teaching them how to use the specific tools of Industrial Engineering that were previously selected. Then come the assignments and "homework".

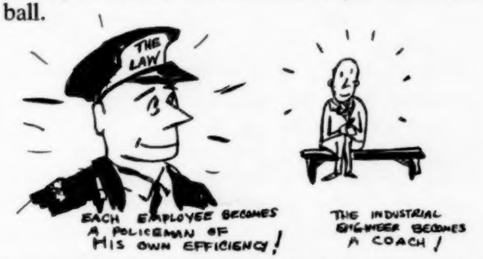
The training phase lasts one week—usually from 1:00 P.M. to 6:30 P.M. daily. After that, they go back to their regular jobs; look at the work through new eyes; and study some specific aspects of it just as though they were Industrial Engineers. While they are doing this they are competing with their fellow members of middle management for some rather exciting citations and prizes.

7. After the "spring try-out" period, usually from a month to three months, we bring our conferees back together for one additional week of intensive training; this time from 9:00 A.M. until 5:00 P.M. daily. During this time master teachers show them how to train their subordinates the same way they were taught during the first round-table. At the same time their "case problems" are reviewed and individual counseling is given. By this time the conferee knows how to increase productivity himself and *how to teach it to others.*

8. He goes back to his own division of the company and selects his first round table group: between 7 and 12 men. He starts out with several two-hour training sessions aimed specifically at attitude-formation in respect to productivity. He explains that in the future "each man will become a policeman of his own efficiency" and that the job of management and methods improvement will become the responsibility of the fellow who does, or controls, the work.


TRY-OUT
NOW READY
HOW TO
① MIDDLE MANAGEMENT MUST LEARN "TOOLS"
② THEN THEY MUST USE TOOLS AND GAIN SKILLS
③ FINALLY THEY MUST LEARN TO TEACH OTHERS THE SAME THINGS
④ FINALLY THEY ARE READY TO TEACH THEIR SUBORDINATES

The Industrial Engineers then proceed to quietly move off the playing field over onto the bench where they coach, but let the line supervisors carry the ball.


THE LAW
EACH EMPLOYEE BECOMES A POLICEMAN OF HIS OWN EFFICIENCY!
THE INDUSTRIAL ENGINEER BECOMES A COACH!

To put them in a position to do this ball-carrying, they receive stimulating training in the basic tools and techniques. For this job, he is aided by a series of visual aids for each "tool". They provide the instructional core for teaching foremen and supervisors how to make process charts, work distribution analysis, chronocyclographs, and so on. Generally, we devote two hours to "how to make" on each tool and then give our conferees specific assignments. Then they go out to their work areas and *use* the tool. Generally, two weeks later they return to the round-table to learn how to analyze and improve the operations they have documented.

9. After the training phase, which usually lasts about three months, the round-tables carry on in the "junior board of directors" tradition. The "instructor" moves out of the picture and becomes available only as requested as a counsellor. The round-tables or boards submit projects through the usual channels covering work they wish to study. Each conferee, in turn, concentrates on his own projects in his department, either independently or with a team of cooperators selected through the round-table.

COST RED-UCTION PROJECT
JUNIOR BOARD
HI GANG!

10. Having had a demonstration of results, each conferee in turn has an opportunity of establishing his own round-table for subordinates in his own department or section. Most participants are eager to carry the message to all possible ears and hearts.

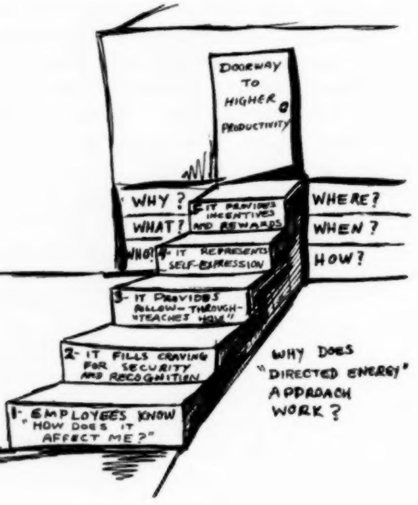
If you ask me today why this method works I am not sure I could answer you, although I am sure I could have given you an articulate explanation ten years ago. Basically, I think it works for some very simple reasons:

First: The company's policy about technological advancement is well known in advance. Everyone can *see clearly* that he will get a break as productivity improves, and he knows exactly how it will be done, and *how it will affect him.*

Second: A feeling-of-belonging is derived from being selected to become a member of a round-table. It satisfies the need for security and recognition.

Third: Once a man is "tapped" for participation he is not forgotten. Management provides training so *he learns how to use the tools.* What use is it to be in favor of higher productivity if you don't know how to go about the task of bringing it about?

Fourth: The round-table provides the needed avenue for Self-Expression. Every type of "resistor" eventually yields to the opportunity of waiting until the other fellow shuts up so he can tell you the *right* way to do it. (Footnote: Frequently he *can*).


DOORWAY TO HIGHER PRODUCTIVITY
WHY?
WHAT?
WHO?
WHERE?
WHEN?
HOW?
5- IT PROVIDES INCENTIVES AND REWARDS
4- IT REPRESENTS SELF-EXPRESSION
3- IT PROVIDES FOLLOW-THROUGH- "TEACHES HOW"
2- IT FILLS CRAVING FOR SECURITY AND RECOGNITION
1- EMPLOYEES KNOW "HOW DOES IT AFFECT ME?"
WHY DOES "DIRECTED ENERGY" APPROACH WORK?

Fifth: The substantial rewards and commendations that go with successful performance in the idea-invention arena stimulate everyone to "get in the act". When everyone gets to thinking about everything he does, and asking "why", you can't help but get results.

To date the results have been most encouraging. To put them in terms you and your presidents will readily understand:

> During the last five years the average return on these programs has been 630% per annum. In other words, the company that invested $10,000 in an installation is getting $63,000 per annum in savings.
>
> Morale has shot up by leaps and bounds. People are happier and healthier. And they are wealthier.
>
> A poll conducted in January 1959 revealed that 87% of company employees participating in Directed Energy Round Tables rated their jobs "the most interesting occupation I can think of" while only 17% of non-participating supervisors and workers rated it this way.

Here is one product of the laboratory that is *working*. The approach of tolerance would teach us there are other methods, and that others have some share of the truth also. I have tried to faithfully report on the one method we *know* works.

I started out by endeavoring to discuss some of the issues in the challenging world of which we are a part, and suggesting to you that the ultimate verdict as to the kind of world we leave behind rests not with politicians, or statesmen, or "great" men (because as Lincoln said "there are no 'great' men"), but with you. This is something *you* can do.

I heard on a "do it yourself" radio program the other day that "to avoid hitting the thumb with a hammer, grasp the handle with both hands". I suggest a different approach. It involves the total *proper* use of our tools, plus an understanding of the end-use accomplishment. That will automatically preclude their use by the I.E. only. When he is the only one to use the tools it is something like the definition I once heard of adultery: "The wrong people doing the right thing."

We live in a world of bewildering technological change, and conflicting political philosophies as to how to live with that change. This challenge need not rob life of all meaning. On the contrary, it can move us mysteriously to the brink of understanding—the infinitely beautiful flash of understanding of the unknown: the perception and comprehension that proves that God has worked in subtle and compassionate ways.

Research is for the curious of all ages. Invention is for the young—the young of all ages. The young know you cannot change man to fit the needs of business, but you can change business to fit the needs of man. *How old* are we?

ESTABLISHING INCENTIVES THROUGH COLLECTIVE BARGAINING

by **DR. WILLIAM GOMBERG**
Adjunct Professor, Columbia University
and
Director, Management, Engineering Department
INTERNATIONAL LADIES' GARMENT WORKER'S UNION, AFL-CIO

Dr. Gomberg received his B.S. degree from the City College of New York, his M.A. degree from New York University, and his Ph.D. degree from Columbia University.

Dr. Gomberg is the author of the books *Trade Union Analysis of Time Study* (1955) and *A Labor Union Manual on Job Evaluation*, the chapter entitled "Trade Unions and Industrial Engineering" for Ireson and Grant's *Handbook of Industrial Engineering and Management*, and numerous articles. He is a member of, and lectures before numerous professional organizations: the AIIE, the American Arbitration Association, the American Economic Association, the American Society for Mechanical Engineers, and many others.

Dr. Gomberg is currently Adjunct Professor of Industrial Engineering at Columbia University as well as the Director of the Management Engineering Department of the International Ladies' Garment Worker's Union (ILGWU), AFL-CIO.

Under his direction, the Management Engineering Department of the ILGWU, AFL-CIO, furnishes free consulting engineering service to garment manufacturers in contractual relations with the Union. A staff of trained engineers and technicians assist the managements of garment plants to make better and fuller use of their plant productive facilities. Because of its pioneering work in the field of Industrial Engineering, the Department has been called upon for consulting work by the United Auto Workers, the International Association of Machinists, the United Rubber Workers, and many others.

WELCOME *Y'all!*

Your Convention Headquarters

BILTMORE HOTEL
Atlanta, Georgia

SCIENCE AND INDUSTRIAL COMPLEXITY: CHALLENGE TO THE INDUSTRIAL ENGINEER

by **MELVIN E. SALVESON**
President
THE CENTER FOR ADVANCED MANAGEMENT
NEW CANAAN, CONN.

Mr. Salveson received his B.S.M.E. degree in 1941, his M.S. in Engineering and Administration in 1947 from M.I.T., and his Ph.D. in Business Administration and Mathematical Economics in 1952 from the University of Chicago.

Since 1941 a summary of his principal activities reads as follows:

—Originated, organized, and directed Business Research Program at Major Appliance Division, General Electric Company, Louisville, Kentucky until transferred to Company Offices in New York.

—Conceived, organized, raised funds for, and directed Management Sciences Research Project at University of California, Los Angeles.

—Organized and directed the planning program for repair and overhaul of submarines at Naval Shipyard, San Francisco.

—Devised and administered design, overhaul, and maintenance program for vessels of Submarine Force, Atlantic Fleet.

—Designed, organized, and taught in production management curriculum, University of California at Los Angeles.

—Conceived, promoted, helped organize, and served as first Vice President of the Institute of Management Sciences.

In 1957, Mr. Salveson founded the Center for Advanced Management in New Canaan, Conn. of which he is president. He is also the author of numerous papers which have appeared in the leading professional magazines.

Abstract

SCIENCE AND INDUSTRIAL COMPLEXITY: CHALLENGE TO THE INDUSTRIAL ENGINEER

by Melvin E. Salveson

The Center for Advanced Management, Inc.
New Canaan, Conn.

SCIENCE is largely the process of devising, testing, and applying new and increasingly useful concepts on the content and character of the Universe. Its purposes are to permit man to understand and to control—for his benefit and utility—the resources of nature. A major step was taken, beginning with Copernicus, when man's concepts on the Universe and its constituents began to depart radically from what his direct practical, or animal, senses tell him. As science progressed, the departure has widened, and correspondingly, man's knowledge and power have increased in proportion.

The ability of man to perceive concepts not made evident by his animal senses is due to his possessing a grossly enlarged forebrain. Curiously, this forebrain serves man by its ability to manipulate concepts—symbols and relations—abstractly. Experience reveals that each man's power is proportional to his ability to manipulate abstractly his concrete environment.

As science and technology have grown industry has become so complex that man's direct perceptions are no longer reliable, or often useful, in manipulating and controlling the enterprise and its operations. Industrial Engineers now need, therefore, wholly new and more powerful concepts, as well as the ability to devise them, in order that they may conceive, manipulate, and design industrial operations for greater productivity. Thus, the modern Industrial Engineer must have his head in the blue skies of science and his feet on the solid foundation of practical application.

Several examples are given wherein this scientific method has been used in industry. In each case, new, creative conceptualization of certain conventional practices have lead to methods which increase profit and productivity. These new solutions are as contrary to usual practical insight and experience as Copernicus concepts were to pre-Copernican science. The examples are taken from organization planning, cost control, budgeting and plant capacity and layout.

MECHANIZED INVENTORY CONTROL

by **R. A. HARRISON**
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Mr. Harrison graduated from Ga. Tech in 1948 with a B.S.E.E. degree and joined International Business Machine Corporation as a Customer Engineer. He was promoted in 1953 to Field Technical Representative, and in 1954 to Salesman. In 1956 he became District Data Processing Representative, and in 1958 Assistant Branch Manager, the position he holds today.

MECHANIZED INVENTORY CONTROL

by R. A. HARRISON

Assistant Manager, Birmingham, International Business Machines Corporation

WEBSTER defines inventory as "an itemized list of goods with their estimated worth." It also shows that the words inventory and invent have a common Latin derivation. One definition of invent is "to come upon or find." Many years ago inventories were small and in many cases control was lacking. The control was to come upon or find.

Webster's definition of control is "To exercise directing, guiding or restraining power." By definition, inventory control is "To direct, guide, and restrain a list of goods."

MONEY AND MATERIAL

Money is only a symbol of the things it will buy. Material things. Inventory. Money in all its forms is given full recognition by business. Guarding, handling and accounting for money has become the subject for intensive planning, and numerous methods have been devised for the treatment of money.

Maybe the money symbolism overshadows the purchasing-power concept because cash is easy to store and handle. Nevertheless, money must be converted to material things if it is to be of any use. And when cash is converted to inventories far more comprehensive records must be compiled and maintained to present the facts for management to evaluate.

There is sound justification for studies of inventory and inventory problems. The recent trend has been to profits based on narrow margins and a more careful and scientific approach to the questions of inventory and inventory controls.

Even a casual glance at business sheets reveals the fact that business organizations have as much as 50% of their capital invested in inventory, and it is safe to say that most concerns have a substantial part of their assets so represented.

Good judgment in the management of these huge investments cannot be consistently based on instinct or hunches. Inventory has often been referred to as the graveyard of American business. It is true that some businesses built their foundations and early successes on lucky speculation in inventory. But, for every such success countless others were wrecked by price declines and changing markets.

Here are the two primary objectives: INVENTORY CONTROL, the maintenance of records of physical quantity; and MATERIAL ACCOUNTING, the financial or money aspect of the inventory.

INVENTORY CONTROL

There are many types of inventory, and you will find a reason for every type and variation—the final use. Inventories are classified and segregated according to the purpose to which they will finally be applied. Here are some of the more common:

Raw Materials. Materials in a natural state such as iron ore and wool fiber; or processed materials for general use like steel rods or woolen yarn. They are normally used to manufacture components or parts for the end product.

Factory Supplies. Items used to maintain operations either in the factory or in the office, but that do not become a part of the finished product.

Work-in-Process. The unfinished products already in the manufacturing operation.

Finished Parts. Completed parts or components used in the manufacture of a product.

Finished Goods. Completed products stored temporarily, awaiting sale or shipment.

Branch Office, Store, and Warehouse Inventories. Inventories maintained at a location away from central headquarters.

Consigned Stock. Merchandise belonging to the manufacturer but in the possession of the retailer.

Service Parts. Parts used to maintain the equipment a company sells or services.

QUESTIONS TO BE ANSWERED

To be of any use to management, inventory records must produce answers to certain analytical questions. And what are these basic questions?

What is in stock?

Is it enough?

Is it too much?

What is on order?

Let's consider these questions and how the answers affect industry:

What is in stock?

Fundamentally, we all like to review our possessions and take note of them. This pride of ownership, however, has little place in the importance the businessman places on the answer to this question. The inventory of the business concern is a tool, a means to achievement of the goal of business everywhere: successful operation. And so the interest in what is in stock will vary in degree, according to the type of business.

In the retail field, for example, it is common practice to keep simple records for the low-priced items, and to depend on frequent physical counts of the stock. For expensive or high-style items, on the other hand, a perpetual inventory is usually maintained. Rapid and accurate analysis by departmental buyers is thus facilitated.

The perpetual inventory is a popular feature among wholesale distributors and jobbers. Most of them maintain current records with a punched card representing each case or shipping denomination of the commodities they handle. Thus, executives in the sales department are accurately informed on what is immediately available for sale and shipment. Industries notable in this regard are wholesale grocery, paint, and electrical supplies.

And so it goes: The sales executive is interested in finished products, and which ones are being sold, which are not. The production men want to know what raw materials are available, and where; what products are in process, and what they represent in raw material or in finished products.

To know what is in stock, then, you must have knowledge of factors such as quantity on hand, receipts, and issues.

Is it enough?

You can't over-estimate the importance of this question. An inaccurate answer to this question can easily result in an out-of-stock condition. To a selling organization, such a condition means the loss of sales and customer satisfaction, or the loss of customers. In a manufacturing program, the lack of even one part may mean halting the production line, or substituting inferior parts. In any case of slowdown or halt in production, fixed overhead continues in the form of supervisory salaries and plant expense. Furthermore, line shutdowns cause unstable labor conditions and a serious morale problem. Let's consider further, lack of service parts can put a vital or expensive production machine out of operation. So, it's clear to see, top management must know "Is it enough?"

Some businessmen place heavy reliance on the experience and ability of a stock clerk, particularly where the number of inventory items to control is small. This is obviously undesirable. And, as the inventory grows in size, it is even more unsatisfactory. To provide positive insurance against out-of-stock conditions, minimum inventories or re-order points are established. A minimum inventory is, of necessity, based on usage experience, with the added consideration of the amount of time necessary to place, process, and receive an order, plus a margin of safety in this lead-time estimate. Therefore, historical records of usage are needed to aid in determining how much should be ordered.

In many manufacturing organizations, production plans are based on a forecast of sales. Each product made by the company is represented in a file by a Bill of Material—a list of all the parts (and quantities) needed to make that product. When production of an item is planned, the Bill of Material is drawn from the file, each item on the list is extended by the planned quantity of finished product, and the total requirement for each part on the list is now established.

This is a particularly swift and accurate procedure with the punched-card method. When you have established the production level, cards initiating a manufacturing order for each product are punched, including the number of finished products planned. Using these as master-selection cards, you can select from the working file of prepunched requirements cards the Bills of Material needed for the units to be manufactured.

From these, requirement cards are reproduced, while the reference data about the order, and quantity to be made, are gangpunched from the order cards—accurately and at high speed. Each card represents a part or subassembly that will be required to complete the order, and the extensions can be machine-calculated to determine the total requirements for the entire production order.

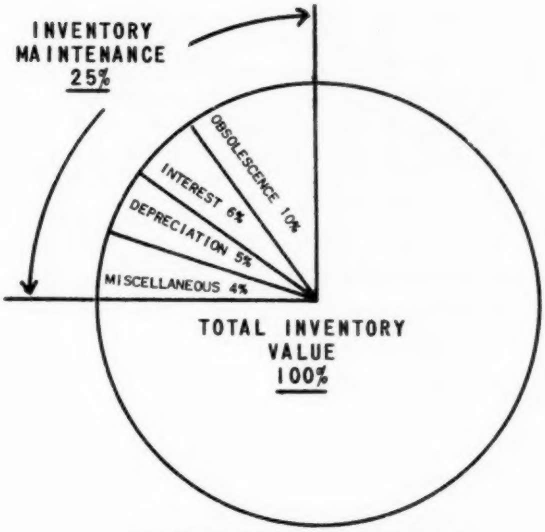
Now your planning officer can develop an accurately documented report, reserving the material needed for the scheduled manufacturing order and serving him as an ordering guide by the anticipation of requirements.

If, in your particular industry, production is initiated by an analysis of orders received, rather than by a sales forecast, the punched-card method is equally fast and efficient. The report is then designed to compare on-hand figures with unfilled orders to established.

Is it too much?

One of the significant differences between a reserve or excess of money and a reserve or excess of materials is the cost of maintenance. It would be extremely unusual for an amount of money to decrease while it is inactive. On the other hand, there is always a maintenance cost in inventory. Although this figure can vary greatly from one industry to another, the annual expense of inventory maintenance often goes as high as 25% of its value. This includes the components shown in Figure 1.

Every businessman must face the grim possibility of obsolescence to some degree. Parts in stock suddenly become obsolete because of a model change, or a new product. This is especially true in the sale of automobiles, where the annual announcements of



MAINTENANCE IS EXPENSIVE

Fig. 1

new models immediately slash into the value of the existing stock of cars. Extreme conditions are well illustrated in the garment and millinery businesses where high-style items cannot be carried from one season to the next, but must be sold at greatly reduced prices, or scrapped entirely.

In a broad sense, the concept of interest as applied to inventory is the gain that would have been earned if the same amount of money had been invested in a different manner. Many high-grade stocks yield annual dividends in excess of 6%.

Normally, we think of depreciation as the reduction in value of a capital asset. In the case of inventories, however, depreciation relates to damage or deterioration due to storage, handling, weather, age, evaporation, or shrinkage.

Miscellaneous charges include the cost of storage and warehouse space, insurance, and taxes.

It is true that the average values illustrated may not apply specifically to your business. Nevertheless, we can agree that all these elements of risk must be carefully calculated and considered whenever you make an investment in inventory.

Another factor to be given careful thought is the possibility of sharp price changes in raw materials. This has been the cause of business failures where a guess that prices were in an upward trend proved wrong. New processes, new sources of supply, or loss of a market and a search for a new one, have resulted in a dropping market price for materials.

There can be no doubt that we must reflect carefully, is it too much?

What is on order?

The cautious financial man is greatly concerned with the question of expenses to be incurred, and when the responsibility must be assumed. Production and scheduling personnel, too, depend to a great extent on a forecast of anticipated availability of materials and parts. And sales and advertising campaigns, planned many months in advance, are vitally interested in what is on order.

IDENTIFICATION

You can recognize the need for accurate identification of each part or raw material when the inventory is established. The identification must be positive. It must be possible to classify like items. And it is very likely that an accurate description will involve lengthy written explanations.

The executive who is responsible for inventory and its movements would find it a colossal task to review a detailed inventory. But he would find a summary report of similar items, associated with each other by an orderly method of classification, a workable and valuable tool.

For these considerations, the use of symbols has been evolved as the simplest way of describing inventory items.

It has become common practice to identify the item first by material classification. This serves as the prefix of the stock number and identifies the major division over which financial accounting control is maintained. This factor, together with the stock number, gives complete identification for each item.

Symbols develop as convenient abbreviations of the terms used in identifying materials, concise in description, and uniform in interpretation. The symbol should describe, rather than designate arbitrarily, and should positively identify a given material.

These are the three most common ways symbol codes are constructed:

1. By numerical codes, where each item is designated by a combination of numbers.
2. By alphabetic symbols, where each item is designated by a combination of letters.
3. By combinations of letters and numbers (PWD-3 to indicate plywood, 3 ply).

The numerical systems are the most commonly used, probably because they are simplest and, yet, have the greatest flexibility. They are easy to use, and have fewer opportunities for confusion.

ELECTRONIC DATA PROCESSING

The possible help electronic data-processing machines can give to top management is especially great in the field of inventory control. Most business con-

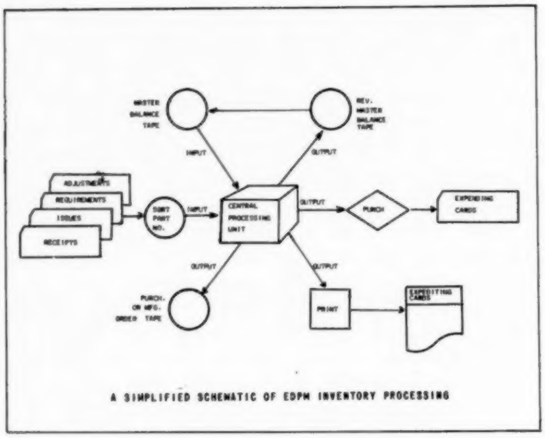


Fig. 2

cerns have so large a part of their assets represented by their inventory that even a relatively small percentage reduction in a large inventory, made possible through better control, can justify the use of electronic data-processing machines.

Actually, these machines go beyond the normal mechanized operations we have discussed, to include analytical work often performed on a manual basis.

For example, after stock records are posted with transaction activity, stock analysts review and study these reports to determine how much should be ordered. Decisions made by these people are on a logical basis. However, the logic is based on the line of reasoning of one individual, or of one small group of individuals. And this line of reasoning will vary considerably from one individual to another, or from one group to another. Quite apart from this, the human factor of error must be considered. A normal number of errors and incorrect calculations can be reasonably expected. And you can see that any mistaken decisions at this level can be very damaging. Failure to order parts can result in assembly shortages at higher levels, and the result of an inaccurate decision will multiply itself.

Most decisions that are based on logical reasoning can be mechanized to provide greater speed and accuracy. Let us consider at this point an installed and operating system on inventory control, material accounting, and procurement. This system utilizes a large scale data-processing system and has been installed in an oil refinery for over two years. The inventory consists of over 30,000 spare parts stored in a central location.

MASTER INFORMATION

Master item information is recorded on magnetic tape. Representative information is as follows.

1. Item code
2. Item description
3. Unit of issue
4. Preferred vendor (if any)
5. Average price
6. Quantity on hand
7. Quantity on order
8. Minimum quantity
9. Reorder point
10. Maximum quantity
11. Reorder quantity
12. Lead time
13. Date of last purchase order with vendor number
14. Period usage

TRANSACTION PROCESSING

Issue, receipts, and adjustments are recorded in punch-card form. For each issue the following computations and decisions are made by the system:

1. Is requested quantity on hand? If yes—reduce balance. If no—create out of stock and expedite notice.
2. Is remaining balance below reorder point? If yes—order. It no—no action.
3. Is remaining balance below minimum? If yes—create expedite notice. If no—no action.
4. Add to period usage.

For each receipt the following computation and decisions are made by the system:

1. Add received quantity to on hand quantity.
2. Reduce on order quantity.
3. Remove purchase order information.
4. Is new on hand quantity above maximum balance? If yes—create notice. If no—no action.

For each order required based on the reorder point the machine checks for a preferred vendor. If the purchasing department has selected a preferred vendor a purchase order is written using the reorder quantity. This information is stored on the master tape. The system follows this purchase order and if the material is not received by the period indicated by lead time an automatic follow up is created by the system. See Figure 2 for a simplified schematic of this system.

This in brief describes a working system that truly works on an exception basis. Only those items that fall outside human stated parameters are called to our attention. These are the only items requiring review and action.

The parameters must be chosen with extreme care. If the reorder point is too low, out of stock conditions will exist. If reorder quantities are too low, too many orders will be written. If the maximums are too high we have failed to control inventory. This is the most critical area of the entire system. A failure here can make the entire system worthless.

ACCOMPLISHMENTS

Let's review briefly what business has accomplished by establishing and analyzing inventory records:

1. Mechanical handling of routine transactions.
2. Mechanical preparation of purchase order information.
3. Efficient and controlled use of capital assets in proportion to inventory investment.

These tangible advantages justify the establishment and maintenance of good inventory-control records. The advantages can be best and most fully realized by weighing them carefully against expenses to be incurred.

MANAGEMENT IN THE ELECTRONIC AGE

by **FRANK F. MIDDLESWART**
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MR. MIDDLESWART received his A.B. degree in 1932 from Marietta College in Mathematics, in 1933 he received his M.A. degree (also in Mathematics) from Ohio State University, and in 1934-36 he did graduate work in Mathematics at Brown University and at the Sorbonne.

From 1937-42, he worked as an actuarial specialist, methods analyst, and in various supervisory assignments for the Equitable Life Assurance Society of the U.S. (1937-41), and for the du Pont Company (1941-42).

During World War II as a member of the U. S. Navy (1942-46), he saw service with NATS in the Pacific Theatre as an air navigation instructor and navigator.

From 1946 to date he has been employed by du Pont in various supervisory positions involving the development of broad management engineering programs such as work simplification, job and position evaluation, craft and clerical measurement, large scale computers, operations research, integrated data processing, and systems engineering.

Mr. Middleswart is the author of "Planning and Measuring Maintenance and Construction Work" for the *Industrial Engineering Handbook* edited by H. B. Maynard, as well as various articles relating to Industrial Engineering.

MANAGEMENT IN THE ELECTRONIC AGE

by FRANK F. MIDDLESWART

Coordinator, Engineering Services, E. I. du Pont de Nemours & Co., Inc.

THE THEME of this conference, "Expanding Horizons of Industrial Engineering", suggests that there are bright new worlds awaiting exploration by the bold and venturesome Industrial Engineer. Those of us who have been probing about the edges of these inviting new areas are keenly aware of the ruggedness of the terrain and the severe demands on ingenuity and mental stamina required for even casual exploration. However, to paraphrase an old saying, "a faint heart never won a new world", so we must gird ourselves for the task before us and move boldly into these exciting new territories.

Other speakers at this conference are describing various new techniques now available to the Industrial Engineer for rigorously attacking the problems confronting management. It is the responsibility of each of us, who would serve our companies and our profession well, to become familiar with these new tools of our trade, and to see that they are exploited appropriately for the benefit of all. To do this we must also recognize that the management environment in the years just ahead of us will be radically different from that in the past. The advent of high-speed data processing equipment, the facility to communicate rapidly, the ability to get from place to place with rocket speeds, the availability of vastly increased amounts of information, and many other similar developments will have increasingly powerful influences on the management environment.

The role of Industrial Engineering, in its broadest sense, is to provide systems, procedures, measurements and controls which management can use conveniently and confidently to manage the business for the optimum good of the workers, the investors and the managers. This is indeed a significantly important responsibility. My purpose in this talk is not to discuss the techniques of the future, but to take a look at management itself. By so doing, it is hoped that it will aid us, the Industrial Engineers who are committed to assist in carrying out the management function, to better understand the responsibilities and challenges that confront us in this complex age of electronics, atoms and space.

THE PRODUCTIVITY CHALLENGE

Most of us, I daresay, are familiar with the glowing predictions of our economists for a large increase in Gross National Product during the next decade or two. However, I wonder how many of us have considered these predictions in the light of recently publicized figures, which show that there is to be essentially no increase in the number of workers in the 18 to 45 age group during this period, while at the same time the number of people under 18 and over 64 will increase markedly. If our Gross National Product is to double as predicted, the labor figures, therefore, imply that our productivity must double. Since very recent figures show that productivity has increased only about 30 per cent to 35 per cent in the past decade, we are forced, by some very elementary arithmetic and casual observation of the situation, to conclude that management, with the aid of the Industrial Engineers, must bear the brunt of the load in upping our productivity so that the forecast and much to be desired growth in Gross National Product may be realized. Furthermore, this takes on added significance when compared to Russia's efforts to outstrip us in this very thing.

If such attention is to be focused on management, we would do well to consider, first of all, just what constitutes the management function.

Before entering into such a discussion, it may be of interest to mention that for the past three years we have had a group of engineers, accountants, statisticians, mathematicians, and philosophers examining the management functions of a complex segment of our Company. This group has been, and is, attempting to prescribe what these management functions are to be over the next decade, giving due consideration to the use of the newest management techniques and electronic equipment for data documentation and processing. Although this study is not yet complete, sufficient progress has been made to give me at least a substantial basis for expressing a point of view about what is ahead for management.

THE MANAGEMENT FUNCTION

For purpose of this discussion, we will define a business man as an organization to produce a product at a profit, or to provide a service at optimum cost. Furthermore, we will consider the management function, whether at a foreman's or clerical supervisor's level, at the chief industrial engineer's level, or at the corporation president's level, to consist of three distinct elements: namely, administrative, planning, and control. We shall designate by the terms administrator, planner, and controller those individuals whose primary responsibility at the moment is to carry out the duties of the respective elements of management. I say "at the moment", for in some instances all three of these elements may be the responsibility of one person who must change hats frequently. At the other extreme, there are larger organizations where each of these elements is the responsibility of distinct groups, even including the administrative element. In between these extremes, one can find examples in which various mixtures of the elements are distributed among individuals or groups or both. Our study has shown that it is not uncommon for these elements to become indistinct in a growing organization unless particular attention is given to defining them at each stage of growth, at each change in organization, or at each new appointment of key personnel. When the responsibility for these elements becomes indistinct, there is often confusion, and most certainly a lowering of management effectiveness.

THE ADMINISTRATIVE ELEMENT

Let us now turn our attention to the management function and consider first the administrative element. It is absolutely imperative that the person or group exercising administrative powers have both the responsibility and authority to establish the organization and policy to permit performance criteria to operate and objectives to be met. By "performance criteria" is meant a set of predetermined attainable standards of performance having well defined lower and upper control limits. Performance within the bounds of the control limits is considered satisfactory; performance outside the limits requires immediate management attention. This means that passive management is out. There can be no "hope so" type of administration. Management must dynamically establish realistic goals and objectives and then take the necessary positive steps to provide the proper environment for meeting them. Those responsible for the administrative element, with the aid of the Industrial Engineer, must establish criteria for assessing performance and authorize revisions of these criteria to adapt them to changing conditions. The administrator must make decisions promptly for all items that are not routinely controlled by the established criteria; this requires him particularly to assess the effect of factors extraneous to his area of control and to take appropriate action. It is in this area that some of the Operations Research techniques are most helpful.

THE PLANNING ELEMENT

The second element of the management function which we shall consider is the planning element. This includes more than simply making plans for the future. Those involved in planning have the responsibility for several activities. Of primary importance is a continual evaluation of the adequacy of the performance criteria which have been established by the administrator. It has been rather common practice to establish so-called standards which represent, in most instances, a sort of average performance for the period immediately prior to the establishment of the standard. From that time on, measurement is made against such a standard and performance judged thereby. If one thinks about this for a moment, one realizes that measuring the output of an organization against such static standards may not really measure the performance of the organization, but rather measures the conformity to a previous average performance, which may or may not be adequate for today's business conditions.

Provisions for proposing revisions to existing performance criteria to keep them current must be a part of the planning element. The Industrial Engineer should have a significant part in this. As a by-product of this evaluation of the adequacy of existing performance criteria, the planner has the responsibility for proposing new criteria applicable to the changing situation. This forces the planner to give attention to the future, for if performance criteria are to be dynamic, they must be based on past performance with due consideration for what is most probably required as adequate future performance. This aspect of planning is greatly assisted by the ability of electronic data processing equipment to digest and make available almost instantly vast amounts of data including information concerning what happened but a few minutes, or at worst, a few hours previously.

Another aspect of the planning element is the evaluation and reporting to the administrator of trends in markets, prices, policies, and general economic conditions which will affect the business. Here conclusions must be based on a discreet analysis of the past, coupled with a prescient understanding of the future. These evaluations must include the analysis of pertinent data arising from outside the company. There are many sources of such data. The principal problem confronting the planner is to select from the tremendous volume of available data those that are related to factors which will affect his business. This will vary from company to company. Those data that may be of real significance to Company "A" in doing an adequate planning job may be misleading if applied to Company "B". Conversely, that which can lead Company "B" to make decisions insuring success of its business, might conceivably lead Company "A" to decisions that would insure its downfall. As I just implied, the planner should possess a goodly supply of prescience.

One further aspect of planning is a constant evaluation of the objectives and goals for the business which the administrator has established. Such goals and objectives are a function of time. Changing economic conditions or international relations can make objectives which are ideal today quite unrealistic tomorrow; or, on the other hand, changing business conditions can make today's hard-to-attain, yet realistic, objectives quite inadequate when considered in the light of tomorrow's potential for a given business. To be useful, goals and objectives must be kept up to date.

THE CONTROL ELEMENT

The third phase of the management function is the control element. Several areas of responsibility for the successful conduct of the business are inherent in this element. Perhaps the most important is the responsibility to measure day-to-day accomplishment against the criteria established by the administrative element for measuring performance, and to report the results to both the planning and the administrative parts of the organization. Historical records of performance must be maintained in such a way that the planners will have adequate and easily accessible data on which to base their work.

In establishing the responsibilities for control, the administrator may delegate to the control organization the authority to make adjustments to the system within prescribed limits in order to keep it within control with respect to established criteria. This does not relieve the administrator of responsibility for making administrative decisions; it simply is a device to permit economic handling of the more routine administrative duties.

One further responsibility of the control element is to produce legal and historical documents required for accounting and tax purposes. These documents, though legally required, do not serve as a dynamic part of the management function. They are a by-product of the data flow through the system which constitutes what I shall call "the management data loop".

THE MANAGEMENT DATA LOOP

Just what is meant by "the management data loop"? This is a concept of the management function which is borrowed from our chemical engineering colleagues who are continually discussing closed loop systems for process control. A closed loop system contains a sufficient number and variety of devices to permit it essentially to control itself. It does this by gathering data at various points in the system, feeding these data into data reduction devices, which measure the current activity against prescribed and preset standards, and then automatically institute necessary action to exercise control over the process. This control may involve resetting of valves or other control devices, as well as recomputing set points to take optimum advantage of changing conditions. Such a system has within it the three elements of management: It has the control function, which continuously gathers information dealing with performance and measures this against the pre-established performance criteria. It has the planning function which tests the adequacy of the criteria for maintaining control and either recomputes and sets up new criteria or informs the human operator that things have gotten beyond its capacity to make such adjustments. However, in such systems the administrative function still is the responsibility of human beings who establish the process specifications and limits before they turn it over to the devices in the process loop.

We visualize the business management function to be analogous to this closed loop concept of process control. In both instances, we must retain the human judgment factor. Neither a chemical process nor a business process can operate long without the intervention of people. I will have more to say about this in a few moments. But first let us take a look at some of the data handling that is required to activate this concept of management.

To make possible the closed loop system of management, we must have adequate current data and facilities for its rapid analysis and accessible storage. Our investigations have shown that we have stored away in most of our organizations considerable useful information that is not available for ready reference or use because of the difficulty in retrieving it, even if those who might use it effectively know that it is there. A new science known as documention is rapidly gaining standing in our business world, and it is furnishing valuable new tools to aid in the management function. Through the use of documentation techniques, valuable information can be stored economically in such a manner that it can be retrieved conveniently and used when required to assist the planning, administrative, and control elements of the management function. Speed of gathering and analyzing accurate data is of utmost importance in these new management concepts.

Mathematical models and statistical methods are beginning to play very important roles in this field. I shall only mention these, since there is not sufficient time to deal with them explicitly. However, to take full advantage of these techniques, one must use electronic data processing equipment. The problem of adequate codes then becomes tremendously significant since we can no longer depend on words or sentences to describe classes of events sufficiently precisely for use in the data handling systems of the future. We have been carrying on a code research project for some months and have found that this is an area of knowledge which can be explored considerably before we will have done much more than just scratch the surface. To make efficient use of the new electronic equipment as an aid to the management function, we must be prepared to tie together all of these techniques, most of which are foreign to the art of management as it has been practiced up until now.

THE MANAGEMENT MAN

So much for the tools and techniques of the management function in this new age. What requirements do all of these concepts put on the management man himself? To fulfill the responsibility for the administrative element, the manager must possess the ability to establish necessary and sufficient criteria by which to assess continuously the performance of his organization. I want to emphasize the words "necessary" and "sufficient". Those of you who have had mathematical training will recall that this is a frequently recurring phrase in proving mathematical theorems. For example, the mathematician says that if thus and so would be true, it is necessary and sufficient that a specific set of conditions exist. Such a set of conditions contain all but only those conditions required to insure that the given statement is true or that a given result will follow. In proving a theorem, it is often easy to establish necessary conditions or sufficient conditions, but to get just that set of conditions which is both necessary and sufficient often takes considerable mental strain. That which is true in mathematics is also true in management. We cannot afford unnecessary conditions, yet we dare not risk trying to operate with insufficient conditions. Some mental strain will be required of the administrator in establishing the necessary and sufficient criteria for his business control.

Another requirement of the management man of the future is that he have an understanding and some knowledge of statistical methodology. By this is not meant that he must be a highly proficient, practicing, theoretical statistician. However, he must have a basic understanding of the power and limitations of the statistical method and sufficient confidence in its validity to use it effectively. This understanding will be required in all three elements of the management function. Somewhere in the planning organization, there will have to be one or more skilled professional statisticians who will serve to handle the vast amount of data required to fulfill the responsibilities of the planning element.

A third characteristic of the manager of the future will be some understanding of and confidence in the use of mathematical models for describing business functions. However, I do not wish to imply that all business will one day be run by formulas. There are too many variables that have high order interactions which we at the moment are unable to express mathematically. These conditions require constant application of human judgment, although many of the basic controls can be expressed as mathematical models. An analogy would be that the mathematical model is the skeleton which supports the body of a business system, the flesh and blood of which is furnished by human judgment.

Another aspect of management which is rapidly coming to the fore is the so-called "management by exception". With sufficient understanding of and confidence in the use of statistical methods and mathematical models, the manager of the future will be able to handle the routine aspects of his management function by the exception principle. Pre-established criteria will serve to define the limits of normal operation so that the manager will be required to give attention only to those items which do not fall within the prescribed normal routine. As a consequence, he will be freed from the perusal of vast amounts of routine, non-informative data which now floods his desk and will have time to devote to the portions of the business requiring his concentrated attention and mature judgment.

Since more and more data will be available to management to form a basis for decisions, the manager of tomorrow must develop an ability to relate to his business a variety of data coming from many sources and to assess the significance of those data on his operations. It is in this area of assessing the significance of reported data that "the men will be separated from the boys" in the management function. An undue amount of attention given to non-significant data, or a failure to recognize the significance of a small change in conditions, or of apparently remotely related information, may be the difference between success and failure. The volume of data that will be available in the future, due to the electronic data processing systems, will require the manager to have the ability to use wider bases of information on which to build his decisions. This ability to comprehend the relative significance of data and to form it into a decision pattern will be aided by some of the operations research techniques we have been hearing about in this conference. However, it will require more mature judgment and a more analytical approach to decisions than has heretofore been necessary or even possible.

One final comment on the matter of the manager of the future is that individual performance will be judged more on how well one manages than on how many people one manages. Since the statistics referred to at the beginning of this talk indicate that we are going to have to get more productivity out of our organizations, this means that the number of persons under our management during the next decade may not increase, but our problems of managing and producing satisfactorily under these conditions will be multiplied many fold. This will bring about new standards against which to evaluate the manager's performance.

CONCLUSION

What do we conclude from all this? Management in the electronic age is going to pose severe new requirements for human judgment. Decisions are going to have to be made more rapidly because we will have more frequent knowledge of the need for making decisions affecting the success of the business enterprise. The manager will have to make these rapid decisions from facts gleaned from a wider range of knowledge than heretofore possible. This will have several effects. For one thing, an error in management judgment will become apparent more rapidly and may have more significant effect than a similar error in today's slower moving business. On the other hand, the continuous exercise of good judgment will be more rapidly rewarding since new measuring devices will be available to determine how successful a manager is from day to day. The introduction of statistical and mathematical methods will require that the manager of the future have a different form of education than has been the norm for managers of the past. Some of the people who will be the managers of the future will have to obtain this education on the job, since they have already completed their formal schooling. Already many companies are embarking on intensive in-company training programs to bring this new knowledge to their management and engineering personnel.

Perhaps we can sum up this entire discussion by saying that the advent of electronics and the development of such management tools as documentation, operations research, integrated data processing and the like, is turning management from an art into a science. As in any scientific field, much exploration remains to be done. Those of us who have Industrial Engineering responsibilities stand on the threshold of a bright but challenging technological advance in the science of management.

NEW TOOLS FOR DECISION-MAKING

by **LAUREN F. SARGENT**
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Prior to joining H. B. Maynard and Company in 1948, Mr. Sargent had many years of practical experience in industrial management and supervision.

As production engineer and production manager for the Bulldog Electric Company, he was responsible for material control planning, scheduling stores, and plant layout.

As division superintendent of the National Tube Company, he directed 1500 employees.

As management consultant for H. B. Maynard and Company, he has worked in a wide variety of industries. He has specialized in a number of industrial problems, several of which required the use of inventory mathematics and linear programming techniques.

Mr. Sargent has spoken on inventory mathematics and linear programming before many professional groups. He is co-author of the book *Linear Programming: Fundamentals and Application* (McGraw-Hill), and has presented a number of papers in the field of Operations Research.

He is a member of Econometrica, the Engineering Society of Detroit, Associate Operations Research Society, and the Institute of Management Sciences.

NEW TOOLS FOR DECISION-MAKING

by Lauren F. Sargent, *Senior Consultant*

Amansco Division
H. B. Maynard and Company, Incorporated

There are a number of new tools that are available to executives that will provide them with information for running their businesses more effectively and profitably than perhaps is now the case.

The specific tools that will be discussed in this presentation are generally grouped under the name of Operations Research.

Operations Research (**OR**) as we define it in this presentation, is the use of mathematics to develop information for business decisions. Some of the mathematical tools are new and some are old. In either case, I'm sure you will recall from your own college days or study that higher mathematics provides a logical and orderly procedure which if followed step-by-step will lead to an answer. Further, that some forms of higher mathematics provide a maximum or minimum answer.

Because of the size and complexity of many business problems, executives and managers at all levels in a firm have found it worth while to take advantage of these two characteristics of mathematics—logic and procedure, and maximum or minimum answers—to provide information for operating the business as profitably and effectively as possible.

The purpose of this paper is to show you by illustration how **OR** can assist an executive. To do this we will together proceed through:

1. A case problem for decision-makers. You will be asked to sit in the seat of the president as we go behind the scenes and discuss the highlights of an actual problem. At each step of the way you will be given an opportunity to check your decision against **OR** information.

2. A brief discussion of the **OR** tools that are available on a practical basis at the present time. Some of the names are queer sounding because they are not management oriented—but don't let that fool you. These tools have and are currently demonstrating real value for many executives as perhaps many of you know.

3. A discussion of some of the uses of these new decision-assisting tools and why their use by people in business will increase in the future.

4. Some management areas in which the application results have been outstanding and which may be well worth your while to consider.

5. Some of the advantages and limitations. **OR** is not a cure-all but can be a decided help in running your business more profitably, making your decisions easier and more factual, and developing some of your people more quickly than is perhaps now the case.

6. What you should do to explore the possibilities of using **OR** in your business.

With this brief introduction, let's discuss each one of the preceding points in turn beginning with "A Case Problem For Decision-Makers."

A CASE PROBLEM FOR DECISION-MAKERS—INTRODUCTION TO TEXTILE PRODUCTS, INC.

Your firm, Textile Products, Inc., manufactures a complete line of fabrics—a total of 15 different products. Because competition is getting stiffer and costs going higher, you have decided that your sales and manufacturing effort for 1958 must be planned carefully—otherwise you face the prospect of shrinking profits.

You have established from trends, indexes, and judgment an industry-wide forecast for each product that you manufacture. You know, of course, that each product must be processed through three general departments to obtain a finished product. The departments are (1) Carding, (2) Spinning, and (3) Weaving. These are the distinct and separate processes—as you find in any manufacturing—required to produce a completed product.

You know from the production and product data that your people have gathered for you the amount of production that you can expect, on the average, to obtain from your facilities and equipment with your general product mix. This information is summarized in Table 1 and Table 2.

As the president, you are responsible for the profitable operation of the business. Consequently, you want to do the following:

1. Establish the most profitable market for Textile Products, Inc., considering the forecast, present product line, facilities, and abilities to produce.

2. Develop a company-wide program to obtain as much of that market as possible.

Table 1 might scare the devil out of you to look at it—but there are two good reasons why it is listed: (1) it lists the kind of information needed to analyze the problems as given; and (2) somebody always asks about the information, and it is easier to put it in and discuss it, rather than talk five minutes about why it wasn't included.

Although we have limited ourselves to three departments and fifteen products, a larger number of departments and products pose no problem to the use of **OR** tools. They just make the problem bigger which will require more time. In this particular problem, **OR** was used to analyze and evaluate the relationships between the profit margin, rates of production, and forecast that are given in Table 1.

Product	Profit Margin /Yd. -$	Industry-Wide Market Forecast - Yards	Production Data By Department		
			Carding Yds. /Lb.	Spinning Yds. /Spindle Week	Weaving Yds. /Loom Week
A	.690	2,500,000	1.35	960	15.9
B	.655	4,000,000	2.25	850	13.5
C	.610	10,000,000	1.35	960	13.4
D	.595	2,000,000	1.60	750	20.0
E	.560	4,000,000	1.70	750	18.6
F	.527	12,000,000	1.55	375	8.5
G	.491	8,000,000	1.50	655	15.5
H	.488	5,000,000	1.60	350	9.7
I	.457	6,500,000	1.23	582	13.4
J	.446	2,500,000	2.26	385	10.9
K	.440	4,500,000	1.39	616	12.2
L	.436	10,500,000	1.50	650	15.0
M	.430	15,000,000	1.62	632	16.7
N	.411	15,000,000	1.55	605	15.1
O	.378	30,000,000	1.96	720	20.4

Table 1. Basic Products, Production Data and Forecast Information.

Basic Assumptions:

Profit margin is the difference between selling price and variable manufacturing costs. General and administrative costs and indirect costs not assignable to a given product are not included.

Margin per yard, rates of production, and plant capacity are considered fixed for the period involved.

Time period is one year.

Market Forecast for the Industry . .	131,500,000 Yards
Average Yield of Carding Department	26,400,000 Pounds
Production Capacity of Spinning Department	50,000 Spindle Wks.
Production Capacity of Weaving Department	2,900,000 Loom Wks.

Table 2. Market Forecast and Available Capacity for the Year.

Assuming that you can produce up to the forecast amount of any product, what is your decision regarding the market for your products:

☐ Devote all facilities to producing 30,000,000 yards of product O @ .378/yd. thereby obtaining a profit margin of $11,340,000? (In other words, go for volume production.)

☐ Produce the forecast amount of each of the products with the highest profit margin until all the available capacity is used? (Every executive knows that given a choice the most profitable course of action is to produce the products with the highest profit margin.)

☐ Toss the whole thing in the waste basket and take off for a round of golf? (With a 2 handicap you may be able to make more money anyway—to say nothing of the exercise and fellowship at the 19th hole.)

☐ Other: Specify. ____________________

____

____

____

Your choice entitles you to take the first giant step up the garden path—and who knows how much profit we will find at the end. To find out, let's take another step and see if we can establish a par or a yardstick for evaluating various programs of profit.

THE PROFIT MARGIN YARDSTICK

On the basis of our experience to date, we find that one of the most important steps—even more important than the final answer in some cases—is to get early agreement on a profit margin yardstick.

The purpose of the yardstick is to have a standard against which the **OR** answer can be measured in order to establish if it is worth while, practical, and obtainable.

We have found that analyzing a past period by one of these new tools and then comparing the **OR** answer to actual performance leads only to trouble. Invariably the **OR** answer is better and as a result the executive responsible for the performance may become defensive. He may construe the difference in profit margin, for example, as a reflection upon his managerial ability. We recommend where possible a yardstick that is less personal.

In the case of Textile Products, Inc., everyone agreed that the Annual Program of Highest Profit Margin Per Product Per Yard, shown in Table 3, represented a reasonable starting place. Under this program the capacity of the plant is used to produce those products having the highest profit margin per yard in descending order up to the forecast amount. When capacity in any one department is used fully, then the profit margin is calculated for the products assigned. This program and profit margin becomes the yardstick to which other programs can be compared. The yardstick for Textile Products, Inc. is listed in Table 3.

	Profit Margin /Yd. -$	Industry Forecast-Million Yards	Annual Production Million Yards	Annual Capacity Utilization			Profit Margin Million $
				Carding Yds. /Lb.	Spinning Yds. / Sp. Wk.	Weaving Yds. / Loom Wk.	
A	.690	2.5	2.5	1,852,500	2,600	157,250	1.725
B	.655	4.0	4.0	1,776,000	4,720	296,400	2.620
C	.610	10.0	10.0	7,410,000	10,400	746,000	6.100
D	.595	2.0	2.0	1,250,000	2,660	100,000	1.190
E	.560	4.0	4.0	2,352,000	5,320	215,200	2.240
F	.527	12.0	9.1	5,870,010	24,300	1,070,280	4.796
G	.491	8.0	0				
H	.488	5.0	0				
I	.457	6.5	0				
J	.446	2.5	0				
K	.440	4.5	0				
L	.436	10.5	0				
M	.430	15.0	0				
N	.411	15.0	0				
O	.378	30.0	0				
Total		131.5	31.6	20,510,510	50,000	2,585,130	18.671
Available Capacity				26,400,000	50,000	2,900,000	

Yards — Bottleneck Department (Capacity fully utilized) — $ Profit Margin

Profit Margin = $18,671,000 Volume of Production = 31,600,000 Yards

Table 3. Annual Program of Highest Profit Margin Per Yard Per Product

Under the conditions and assumptions of the problem, will the program listed in Table 3 return the highest margin possible from the facilities and products available? Call it as you see it. Do you agree that manufacturing products with the highest profit margin per yard will provide the largest profit margin?

- ☐ Yes
- ☐ No
- ☐ We'll take it! It's a damn sight better than we have been doing.

THE PROGRAM OF HIGHEST TOTAL PROFIT MARGIN

Table 4 shows the program as calculated by Linear Programming, which is one of the new **OR** tools to which the title of this paper refers.

A glance at the table will show you that there are some similarities and differences between the yardstick of Highest Profit Margin Per Yard shown in Table 3 and the program shown in Table 4. Both programs show that it is a good idea to manufacture Products A, B, C, D, and E up to the forecast amount. In place of the Product F shown in Table 3, **OR** indicates that profit margin can be improved by approximately $2,500,000 by manufacturing Product G up to the forecast amount and using the remaining capacity to manufacture Product L. Both of these products have a lower profit margin per yard than Product F which was displaced, yet the total profit margin is higher. The increase will come from managing existing facilities more effectively—in short managing as well as you possibly can.

Product	Profit Margin /Yd. -$	Annual Industry Forecast in Million Yards	Annual Production in Million Yards	Annual Capacity Utilization			Profit Margin Million $
				Carding	Spinning	Weaving	
A	.690	2.5	2.5	1,852,500	2,600	157,250	1.725
B	.655	4.0	4.0	1,776,000	4,720	296,400	2.620
C	.610	10.0	10.0	7,410,000	10,400	746,000	6.100
D	.595	2.0	2.0	1,250,000	2,660	100,000	1.190
E	.560	4.0	4.0	2,352,000	5,320	215,200	2.240
F	.527	12.0					
G	.491	8.0	8.0	5,336,000	12,240	516,000	3.928
H	.488	5.0					
I	.457	6.5					
J	.446	2.5					
K	.440	4.5					
L	.436	10.5	7.883	5,257,960	12,060	575,800	3.437
M	.430	15.0					
N	.411	15.0					
O	.378	30.0					
Total		131.5	38.383	25,234,460	50,000	2,556,650	21.240

Yards — Bottleneck Department — $ Profit Margin

Profit Margin = $21,240,000 Volume of Production = 38,383,000 Yards

Table 4. Annual Program of Greatest Total Profit Margin

Now That You Have Seen This Program, What Is Your Reaction?

- ☐ I don't believe it.
- ☐ I better change my decision about Table 3.
- ☐ I'm going to have Accounting check this before I commit myself.

ALTERNATE REALISTIC SALES PROGRAMS

Realistically, you know that you cannot expect to obtain the forecast amount of the products with the highest profit margin unless you have a monopoly. For one thing there are other manufacturers in the business, and they will get a share of the market—if for no other reason than the fact that buyers want more than one source of supply, even as you yourselves do. For another, you may have to furnish products of lower profit margin in order to sell the products of highest margin—in order to provide your customers with the "complete line." Faced with these realities what should you do?

- ☐ Relax and take it as it comes.
- ☐ Go into another business, where the customers aren't so tough.
- ☐ Fight with the Sales Department—They are good ones to blame it on.
- ☐ Analyze the situation and develop realistic programs of sales and production.
- ☐ Install punch card equipment—we can do a great deal with it.

Obviously, alternative four—analyze the situation and develop realistic programs of sales and production—is the soundest one available to you.

Based on this assumption then, we get together with the sales department and forecast sales of those products which the **OR** analysis indicates we should actively seek. The forecast as developed is shown in Table 5.

	Revised Amount Million Yards	Carding Pounds	Spinning Sp. Weeks	Weaving Loom Weeks	Profit Margin $
A	1.0 (2.5)	741,000	1,040	62,900	690,000
B	2.0 (4.0)	888,000	2,360	148,200	1,310,000
C	3.0 (10.0)	2,223,000	3,120	223,800	1,830,000
D	2.0 (2.0)	1,250,000	2,660	100,000	1,190,000
E	4.0 (4.0)	2,352,000	5,320	215,200	2,240,000
G	3.0 (8.0)	2,000,000	4,590	193,500	1,473,000
L	2.0 (10.5)	1,334,000	3,060	133,400	872,000
	17.0	10,788,000	22,150	1,077,000	9,605,000

Table 5. Revised Sales Program #1

Under these circumstances you have capacity available and you want to make the decision as to whether it is more profitable to manufacture product M or O, or both. You must produce one or the other to make the forecast. What would you do?

☐ Manufacture product M, at a margin of $0.430 per yard?

☐ Manufacture product O, at a margin of $0.378 per yard?

☐ Manufacture some combination of both.

☐ Leave it to Joe Smith to decide. Good old Joe will take care of it and then we won't have to worry about it.

If we let Operations Research tell us which of the two products to manufacture, we find that we should produce all we can of Product O—the product with the lowest profit margin in the line. In other words, we produce a product with a profit margin of $0.378 instead of Product M with a profit margin of $0.430 or even Product F with a margin of $0.527. This decision is probably contrary to your expectations and what you would usually decide.

The special feature that the **OR** analysis brings to this problem and the decision-makers is that it considers the rate at which profit can be made on each product in the mix and then allocates productive hours according to the profit return. Even an Einstein is likely to find this process of evaluation and allocation extremely difficult without the use of an effective method. We believe that **OR** methods when used in this way can be helpful to business people—particularly when the problems are large and complex.

If the sales department says that you can sell only 15,000,000 yards of the 20,040,000 that can be produced, then you will have capacity available for the manufacture of other products.

Using the same procedure, we find that the remaining capacity should be devoted to manufacturing 4,070,000 yards of Product I with a total profit margin of $1,856,000. The total program under these conditions is listed in Program IV of Table 6.

Table 6 gives a comparison of the four programs that we have been discussing. It is interesting to see that Program IV will produce approximately the same income as Program III, and do it on a million less yards. It is also interesting to see that Product F never comes into a higher profit margin solution despite its relatively high margin per yard. Producing F reduces profit. Without this kind of analysis it is quite possible that management would not see either of these conditions.

			PROGRAM I		PROGRAM II		PROGRAM III		PROGRAM IV	
			HIGHEST MARGIN BY PRODUCT		GREATEST TOTAL PROFIT MARGIN		REVISED SALES PROGRAM #1		REVISED SALES PROGRAM #2	
PRODUCT	PROFIT MARGIN $/YARD	INDUSTRY FORECAST MILLION YARDS	QTY.	MARGIN $	QTY.	MARGIN $	QTY.	MARGIN $	QTY.	MARGIN $
A	.690	2.5	2.5	1.725	2.5	1.725	1.0	.690	1.0	.690
B	.655	4.0	4.0	2.620	4.0	2.620	2.0	1.310	2.0	1.310
C	.610	10.0	10.0	6.100	10.0	6.100	3.0	1.830	3.0	1.830
D	.595	2.0	2.0	1.190	2.0	1.190	2.0	1.190	2.0	1.190
E	.560	4.0	4.0	2.240	4.0	2.240	4.0	2.240	4.0	2.240
F	.527	12.0	9.1	4.796						
G	.491	8.0			8.0	3.928	3.0	1.473	3.0	1.473
H	.488	5.0								
I	.457	6.5							.407	1.856
J	.446	2.5								
K	.440	4.5								
L	.436	10.5			7.883	3.437	2.0	.872	2.0	.872
M	.430	15.0								
N	.411	15.0								
O	.378	30.0					20.04	7.574	15.0	5.670
TOTALS		131.5	31.6	18.671	38.38	21.240	37.04	17.179	36.07	17.135
				Profit Margin		Profit Margin		Profit Margin		Profit Margin

Table 6. Comparison of Alternative Programs

By the time you have analyzed the possible sales alternatives in this way, you have a sales objective that is realistic. You know that you cannot achieve the Greatest Total Profit Margin Program, but you have accomplished two important things. These are as follows:

1. You have developed a selective sales objective that will permit you to make the best profit margin under the existing commercial restrictions.
2. You have oriented the sales department so that they see the interrelation between product mix and profit margin per hour of production.

The next step is to translate this sales objective into demands for production capacity. This is done by programming the realistic sales objective in the same manner as the market potential was analyzed. This time, however, your purpose is to determine how much capacity you must have in each department to meet these proposed sales. If the product mix creates a bottleneck that you cannot economically eliminate, you can measure the profit you must forego. These bottlenecks, of course, also highlight the operations where new equipment or methods improvements can be used to increase production or reduce costs, which in turn helps you move toward the most profitable portion of our market. For example, analysis will show that you can increase your profit margin $285 for each additional hour of production that you can gain from the Spinning Department which is the bottleneck. On this basis you can afford to invest in methods improvements that increase production or even work a certain amount of overtime. In this manner, you can arrive at a final sales program that coordinates sales effort with engineering effort and production capacity to maximize profits.

So that you will have the complete picture of the analysis, we have included the business gaming solution to Program II as well as the general steps for a company-wide program for aligning sales and manufacturing effort with the most profitable portion of the market. Table 7 lists the steps in the company-wide program and Table 8 gives computations and rules for calculating Program II.

1. Forecast by product the total sales demand for the market served.
2. Determine the program which will produce the highest attainable margin within the limits of the forecast and plant capacity.
3. Modify this program as required to arrive at realistic sales goals.
4. Determine the plant capacity required to meet these sales requirements.
5. Compare the costs of increased capacity with the additional profit to be gained --- when capacity limits sales.
6. Adjust the final sales objective or increase capacity according to the cost comparison.
7. Plan engineering studies to increase production and reduce costs where desired.
8. Develop a selected sales program to meet sales objectives.
9. Develop the sales and manufacturing procedures and reports required to sell and produce the most profitable product mix.
10. Measure the performance of sales, engineering, and production against final sales objective, planned manufacturing capacity and utilization, and desired cost reductions.
11. Correct sales, engineering, or production programs as required to maximize profits.

Table 7. A Company-Wide Program for Aligning Sales and Manufacturing with the Most Profitable Portion of the Market

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1. Program Data

(i) Product ↓	Product Profit per Yard P_i	Carding Dept. Yds. per lb. O_{i1}	Spinning Dept. Yds. per Week O_{i2}	Weaving Dept. Yds. per Week O_{i3}	Market Limits Yds. X 10^{-6} M_i
1	.690	1.35	960	15.9	2.500
2	.695	2.25	850	13.5	4.000
3	.610	1.35	960	13.4	10.000
4	.595	1.60	750	20.0	2.000
5	.560	1.70	750	18.6	4.000
6	.527	1.55	375	8.5	12.000
7	.491	1.50	665	15.5	8.000
8	.488	1.60	350	9.7	5.000
9	.466	2.26	385	10.9	2.500
10	.457	1.23	582	13.4	6.500
11	.440	1.39	616	12.2	4.500
12	.436	1.50	650	15.0	10.500
13	.430	1.62	632	16.7	15.000
14	.411	1.55	605	15.1	15.000
15	.378	1.96	720	20.4	30.000

Capacity Restrictions (C_{j1}):
Carding Dept. (j=1) ≤ 26.4 x 10^{-6} lbs.
Spinning Dept. (j=2) ≤ 20.0 x 10^{-3} weeks
Weaving Dept. (j=3) ≤ 2.9 x 10^{-6} weeks

(i) ↓ E_{ij}	2. Game at K=1 (j)→ 1	2	3	3. Game at K=2 1	2	3
C_j→	26,400,000	50,000	2,900,000	24,622,222	45,294	2,603,704
1	24.592	33.120	31.926	22.935	30.003	28.664
2	38.907	27.838	[illegible]	xxx	xxx	xxx
3	21.760	29.280	23.705	20.276	26.524	21.883
4	25.132	22.312	34.510	23.440	20.212	30.984
5	25.132	21.000	30.206	23.440	19.023	27.120
6	21.565	9.881	12.991	20.113	8.951	11.664
7	19.444	15.989	22.070	18.135	14.122	19.815
8	20.619	8.940	13.727	19.231	7.736	12.384
9	26.610	8.936	14.098	24.518	7.778	12.658
10	14.840	13.299	17.759	12.403	12.047	15.965
11	16.146	13.552	15.567	15.059	12.276	13.977
12	17.266	14.170	18.966	16.103	12.836	17.088
13	18.390	13.588	20.825	17.152	12.309	18.697
14	16.818	12.432	17.998	15.685	11.262	16.159
15	19.559	13.608	22.362	18.242	12.327	20.078

(i) ↓ E_{ij}	4. Game at K=3 (j)→ 1	2	3	5. Game at K=4 1	2	3
C_j→	22,700,370	42,490	2,446,471	21,520,370	40,023	2,346,471
1	xxx	xxx	xxx	xxx	xxx	xxx
2	xxx	xxx	xxx	xxx	xxx	xxx
3	18.751	24.999	19.998	17.722	23.437	19.180
4	21.677	19.050	29.113	xxx	xxx	xxx
5	21.677	13.930	25.482	20.487	16.810	26.441
6	18.600	8.436	10.959	17.579	7.909	10.511
7	16.771	13.310	18.618	15.850	12.478	17.857
8	17.784	7.251	11.580	16.308	6.836	11.107
9	22.951	7.331	11.893	21.692	6.873	11.407
10	12.800	11.355	14.982	12.097	10.645	14.369
11	13.926	11.571	13.132	13.162	10.848	12.596
12	14.892	12.098	16.000	14.075	11.344	15.346
13	15.862	11.601	17.548	14.791	10.877	16.850
14	14.506	10.614	15.183	13.709	9.951	14.563
15	16.870	11.619	18.865	15.944	10.893	18.094

(i) ↓ E_{ij}	6. Game at K=5 (j)→ 1	2	3	7. Game at K=6 1	2	3	8. Game at K=7 1	2	3
C_j→	14,112,963	29,606	1,600,202	11,760,022	24,273	1,385,148	6,426,689	11,675	869,03
1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
5	13.435	12.435	18.309	xxx	xxx	xxx	xxx	xxx	xxx
6	11.528	5.851	7.874	9.606	4.797	6.205	5.250	2.307	3.893
7	10.394	9.231	13.377	8.661	7.558	10.541	xxx	xxx	xxx
8	11.323	5.057	8.320	9.185	4.146	6.557	5.039	1.994	4.113
9	14.225	5.084	8.545	11.854	4.168	6.734	6.478	2.005	4.225
10	7.933	7.875	10.764	6.611	6.456	8.482	3.613	3.105	5.322
11	8.531	8.024	9.436	7.192	6.579	7.435	3.931	3.164	4.665
12	9.230	8.390	11.496	7.691	6.879	9.059	4.203	2.309	5.683
13	9.831	8.046	12.623	8.192	6.596	9.947	4.477	3.173	6.240
14	8.291	7.361	10.909	7.492	6.035	8.597	4.094	2.903	5.393
15	10.456	8.058	13.554	8.713	6.606	10.681	4.762	3.177	6.701

9. Recapitulation of Solution

Decision D_k	Decision Element E_{ij}	Yards Produced M_i	Capacity Utilization Carding C_{i1}	Spinning C_{i2}	Weaving C_{i3}	Realized Profit M_i P_i	Product
1	2.3	4.000	1.778	4.706	.296	2.680	2
2	1.1	2.500	1.852	2.604	.157	1.725	1
3	4.2	2.000	1.250	2.667	.100	1.190	4
4	3.1	10.000	7.407	10.417	.746	6.100	3
5	5.2	4.000	2.353	5.333	.215	2.240	5
6	7.2	8.000	5.333	12.598	.516	3.928	7
7	12.2	7.883	5.059	11.675	.506	3.437	12
$\sum_{k=1}^{7}$		38.383	25.032	50.000	2.536	21.240	

Table 8. Program of Highest Total Profit Margin Textile Products, Incorporated

This is the kind of analysis that can be done when **OR** tools are used by people with skill in their application. The particular firm that used this analysis has done exceedingly well at a time when competition is fierce. The story is wonderful—highly satisfying to them and to us. In fact, the firm is going through the analysis for the third time. They wouldn't think of planning without the information that the **OR** analysis gives them.

WHAT ARE SOME OF THE OPERATIONS RESEARCH TOOLS?

It's not important for the executive to know *why* these techniques work and *how* they work. What is important is that these techniques do identify a best solution for an executive to consider in his thinking and planning.

Each one of these tools provides a *system,* where it applies, for weighing, relating, and analyzing the desirability of the alternatives among which the executive has to make a choice. With the desirability expressed in terms of costs, or profits, or service, the executive is in a better position to make a decision. And even if he doesn't elect to follow the answer provided by the technique *today*—at least he has some idea of what he is foregoing when he elects to do otherwise and can plan more intelligently for tomorrow.

WHAT IS OPERATIONS RESEARCH?

As used in this presentation, Operations Research is the application of the procedures, principles, and logic of mathematics to business problems. The objective is to provide decision-makers with better information than they now have by providing procedures for evaluating alternatives and choices with which they are faced.

Some of the most useful Operations Research tools at the present time are the following:

1. Linear Programming
2. Waiting Lines
3. Game Theory
4. Search Theory
5. Monte Carlo Theory

What are the reasons for the increasing use of these tools?

There are a number of reasons why management is increasing the use of these new decision-making tools. They assist management with its problems by:

1. Providing better yardsticks or guides for operating the business. In some cases they point out the fallacy in some of the existing management yardsticks such as profit margin and inventory turnover.
2. Providing useful analyses before the fact such as how to use existing resources and facilities and where improvement should be sought or made.
3. Providing better ideas and more understanding of problems through the exploration of alternatives and possibilities.
4. Providing a system and order for solving and analyzing problems which can be reduced to procedures that people can follow.
5. Providing an indication of when the best answer and program have been reached.

More generally the value of these tools results from:

1. Improvement in the effectiveness of the individual executive and manager—higher batting average.
2. Development and training of management personnel.
3. Improvement, dollar-and-cents-wise, in the operation of the business.

Where Can The Tools Be Used?

A very few of the areas of use include the following:

1. Profit Planning
   —Matching plant capacity to sales requirements to capture as much of the market as possible.
   —Allocating customers' orders among several plants considering distribution and manufacturing costs.
   —Directing capital expenditures for new plants and equipment.
2. Sales Planning
   —Forecasting sales.
   —Locating retail outlets and warehouses.
   —Measuring the effect of advertising on department store sales.
3. Production Planning
   —Stabilizing production and employment to meet sales.
   —Determining which parts to make and which to buy.
   —Loading machine centers.
4. Cost Cutting
   —Processing utility billing data.
   —Analyzing the operation of a railroad classification yard.
   —Computing and preparing insurance premium notices.
5. Personnel
   —Determining equitable salaries and sales incentives.

What Should You Do?

There are a number of steps that can be taken depending upon where you are now:

1. If you have people interested in **OR** or are doing **OR** work now, you should make certain that they do not overlook realistic problems. Don't let them take five years to get ready to reach for the moon and completely overlook some of the everyday improvements that will more than pay for the investment in their time. You and your management should also get into it deeper by having the **OR** people present an explanation of what they are doing and expect to achieve.
2. If you have no one doing **OR** work or if you are considering doing some, make sure that you select someone with a consuming interest in **OR**. Don't give it to someone as an assignment. You must provide training and select a problem that gives your people a chance to crawl before they walk. Some of the areas of use listed earlier in this passout—particularly in the production planning area—offer good places to get started.

Under any circumstances, proper training of people and executive enthusiasm and support are essential. The returns can be spectacular.

CONVERSION TO ELECTRONIC DATA PROCESSING
OR
CONVERSION FROM A MANUAL TO AN ELECTRONIC SYSTEM

Dr. Grace Murray Hopper received her B.A. degree from Vassar in 1928, her M.A. in 1939 from Yale, and her Ph.D. in 1934, also from Yale — all in Mathematics. She is a Phi Beta Kappa and has been the recipient of numerous honors among which are one scholarship and three fellowships.

From 1931 through 1944, Dr. Hopper taught mathematics at Vassar, rising from Assistant in Mathematics to Associate Professor. In 1944 she left Vassar to become a Mathematical Officer in the U. S. Navy's Bureau of Ordnance. During this period (1944-6), she worked on Harvard University's Computation Project — the programmers Mark I, II, and III — and in 1946 became a Research Fellow in Harvard's Engineering Sciences and Applied Physics Computation Laboratory. Then, in 1949 she joined (as Senior Mathematician) the Eckert-Mauchley Computer Corp. of Philadelphia which became in 1950 the Eckert-Mauchley Division of Remington Rand. After being a Senior Programmer for Remington Rand for two years, in 1952 she was made Systems Engineer and Director of Automatic Programming Research, the position she holds today.

Dr. Hopper belongs to numerous professional organizations and is the author of many papers and published articles on programming and computers. She is also the co-author of volumes of the Annals of the Computation Laboratory of Harvard University.

CONVERSION TO ELECTRONIC DATA-PROCESSING
OR
CONVERSION FROM A MANUAL TO AN ELECTRONIC SYSTEM

by DR. GRACE MURRAY HOPPER
Systems Engineer and Director of Automatic Programming Research
The Eckert-Mauchley Division of Remington-Rand

IT is curious that in mentioning a conversion process, most people will describe it as "manual to punched-card" or "punched card to magnetic tape", thus throwing all emphasis on conversion of .the data-format. Actually there are three forms of conversion involved: conversion of people, conversion of systems, and conversion of data. It cannot be too strongly stated that the first is the most important and that from it the other two derive. Suppose a manual sysem or a semi-manual system involving some punched card machines is to be converted to an electronic data-processing system.

In the semi-orderly confusion of a feasibility study, it has been decided to install a computer because "it will reduce personnel requirements and hence costs" or because "it will speed up paper work". While both reasons are valid, neither will produce as successful an installation as one based on "it will provide the ability to produce better (quality) and more timely information for management decision". Reduction of costs and speed-up of paper work will follow in such an installation from better decisions and from fewer but more informative reports.

In such a case, before evaluating and redesigning the system, personnel must be retrained to think in terms of the new technique. Obviously, the system must eventually be programmed for the computer and programmers must be trained. Not so obviously, systems designers must be trained to think in terms of the limitations and capabilities of the new equipment. Those who prepare input to the new system must be trained in the stringent requirements of a computer for correct—not almost correct—data. Still less obviously, the management personnel who are to receive and use the reports prepared by the computer must learn what the computer can produce and must stipulate and accept the more sophisticated reporting of which a computer is capable.

Data may be classified as consisting of permanent records and temporary records. Data contained in temporary records affects the data contained in the permanent records. It may add to, delete from, or change the permanent records. Data may be recorded in a variety of ways: It may be handwritten, typed, unityped, or keypunched. It may appear on paper, index cards, punched cards, magnetic tape, or paper tape.

Records are used to compile reports from which management can make intelligent decisions. From time to time, management changes its mind as to what data it needs in reports. In such cases, new data is produced, but data which is no longer useful is seldom deleted. It continues to be produced out of habit or "just in case". Over a period of years, reports tend to increase in number and in size. On the other hand, there are also types of reports which management could use, but which are too expensive to produce manually or by conventional mechanical methods.

The first major step in converting from a manual or mechanized system to a computer system is the determination of the necessary and the desirable output reports. The existing system is usually carefully examined to determine the nature of the data contained in every report and the format, frequency, and distribution of every report. Questionnaires may be submitted to the people who use the reports in order to determine how, when, and what fields of data are actually used by whom they are used. When the results are tabulated, it is usually found that some reports can be abolished, others can be consolidated by the elimination of many fields of data unnecessary at the final reporting stage. The distribution of some reports can be reduced. The format, frequency, and distribution of output reports is thus determined, including those reports which were not produced under the existing system for reasons of time or economy.

The next point of attack is the source data. Many of the requirements imposed on the source data are evident in the format of the output required. In some cases, however, it is necessary to determine what fields of input data are required in the computation parts of the system or development of certain output data fields. (The computation and processing are not included in this discussion).

Having determined the source data required, it becomes necessary to ascertain the nature of every field. What is its maximum length? Is it alphabetic, numeric, or alphanumeric? Is it signed? Where is the decimal point located? Are leading zeros suppressed? What are the legal ranges of numeric quantities in the field? Exactly what codes are valid? Furthermore, what are the minimum, normal, and maximum volumes of the files? What is the rate of change; i.e., how many additions, changes, and deletions per file per cycle?

With this information tabulated, it is possible to design a format for each input "file". Wherever possible, existing source data files should be consolidated to eliminate duplication and provide for simpler maintenance and control. If existing files are already punched in cards, the cards can be converted to tape. If the data is not in the desired format, it can be edited by a plugboard or an editing routine. If the source data is not already on punched cards, a procedure must be set up for the keypunching or unityping of the files. If the existing files or source documents are in poor condition, it is advisable to prepare a standard form for the transcription of the data so that it can be keypunched or unityped in a straightforward manner with a minimum of errors. Care in defining this procedure and in training personnel can save many hours of time during actual conversion running on the computer. (Does the computer expect "Fort Wayne, Ft. Wayne or Ft Wayne? New York, N.Y., New York City, N.Y. or N.Y., N.Y.?)

In some installations it may be necessary to convert existing data to more than one medium. For example, in a system with a communications network it may be necessary to convert punched-card files to paper tape for use in district sales offices and to magnetic tape for use in the data-processing center. In such cases, the idiosyncrasies of *both* media may affect the format of the input.

Further, the very nature of the data may affect the input format; for example, a numeric field which is frequently used in computation should be allowed a full word in a fixed-word-length computer for ease in processing. On the other hand, fields which are seldom used can be packed to save space. It is usually advisable to condense the records as far as possible; at the same time some space must be allowed for the inevitable expansion requirements which will develop.

Generally, however, the format of output reports or of the master files will dictate to a large extent the format of the input records. In other words, the ultimate destination and arrangement of the data should be considered in the design of input formats. Information which is grouped together in final form should be grouped together as early as possible in the system and carried together through the system for more efficient handling.

As "permanent" records are keypunched or unityped and converted, changes must be cut off, and control must be maintained over "temporary" records so that the converted records can be updated when the system is cut over.

During this period a conversion system must be designed and programmed. This job should not be underestimated. Depending upon the volumes and the complexity of the files, it may consist of fifty or more machine "runs". However, many of these runs will be "canned" sequence checks, sorts, and merges—already coded runs which are usually supplied by the manufacturer. It may be necessary, sometimes, to modify these routines to comply with standards adopted by the installation, if these differ from those generally accepted for the given type of computer.

In general, the conversion system should include the following characteristics:

1. Every raw input file should be sequence checked.
2. Wherever possible, the data should be validity checked.
3. Item sizes (record lengths) should be reduced to a practical minimum as early as possible in the conversion processing.
4. Source data from different files should be consolidated as early as possible. As these files are brought together, checks for valid combinations of data can be made.
5. Listing of erroneous data should be produced, coded in such a manner as to facilitate correction of the records. The system should be capable of accepting corrected records reintroduced at a point where their validity can again be checked.
6. The system should be capable of accepting additions and deletions and killing duplicates throughout the conversion period. Other changes, however, should only be made through the normal updating process of the permanent system in order not to complicate the conversion system.
7. The system should produce any desired listings or printed or punched records of the files which it creates.
8. The conversion system is a good place to compile statistics on the types of data in the various files. Such statistics can be useful to programmers in improving the efficiency of the permanent system.
9. Emphasis should be placed upon getting all routines checked out as quickly as possible. Automatic coding and canned routines should be used wherever possible.

Normal debugging procedures should be followed for the conversion system. After every run is checked out on fabricated data, representatative volumes of actual data should be run through the entire system.

It has been assumed in this discussion that analysis and programming of the permanent data-processing system has been proceeding in parallel with the programming of the conversion system.

After the permanent system has been checked out on fabricated data, it is customary to run the computer system in parallel with the existing system in order to check the results of the computer system. It is necessary that the master files be produced by the conversion system in time for use in this parallel operation. The temporary or change records which have accumulated since the permanent records were cut-off should be keypunched or unityped just prior to the parallel operation. This type of data will be normal input to the computer system and is therefore sequence and validity checked as part of the permanent computer system. Thus, the accumulated changes can be introduced and the converted master files updated during the parallel operation.

Personnel concerned with the application must be further retrained during the parallel operation. They must be familiarized with the forms to be used for introduction of data into the system, proper completion of those forms, and channelling to the data-processing center. They must also be informed as to the format, type, and frequency of information to be derived from the system.

The parallel operation itself is an uneconomical procedure and should be continued only until the computer system has proved itself. However, the results of the computer system must be thoroughly checked during the parallel operation. Wherever possible, it is advisable to cut over to parallel operation and later to production on a gradual basis. For example, one district, one shop, a one stock class could be cut over at one time. As the parallel operation proceeds, the rate of cut-over can be increased.

All during the process just described, everyone concerned with the computer center, even quite remotely, has been learning what a computer will do for him—in courses, by reading, by programming and finally by debugging the data, the runs, and the system. This discussion has covered the conversion of data and the conversion to computer operations. Of equal and, perhaps, greater length and surely of greater complexity would be the discussion of conversion of the system and conversion of people, thus running well beyond the time allowed.

Much of what has been said may seem obvious; most of it, however, had to be learned through experience with a most exacting tool: an electronic computer. I should like to express my thanks, for his help in producing this outline, to Edward F. Somers of our Automatic Programming Development Group who has guided more than one conversion, and to our installations who by their valiant efforts have been converted and thus supplied the experience upon which these remarks are based.

ENGINEERS ARE PEOPLE

by **NOAH H. LANGDALE, JR.**
President
GEORGIA STATE COLLEGE
ATLANTA, GEORGIA

MR. LANGDALE graduated from the University of Alabama with an AB degree in 1941. While at the university he was elected to Phi Beta Kappa fraternity as well as receiving many other honors. From 1942-1946 he served with the N. S. Navy in both the North Atlantic and the South Pacific.

In 1948 he received the LL.B. degree, and in 1950 the M.B.A. degree, both from Harvard University, and in 1951 entered the practice of Law in Valdosta, Ga. During the academic year 1954-55, he served as part-time instructor of Economics and Social Sciences at Valdosta State College, Valdosta, Georgia. There he founded, in 1955, the Department of Accounting, Economics, Secretarial Science, and Business Administration and served as Departmental Chairman. He was appointed to the presidency of Georgia State College of Business Administration by the State Board of Regents on July 10, 1957.

Mr. Langdale is a member of many business and fraternal associations including the Georgia Bar Association, American Bar Association, Georgia Education Association, Atlanta Rotary Club, and the Benevolent Protective Order of Elks.

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ATLANTA - 1959

ROBT. S. WOLTMAN
Director of
Planning

Welcome,
Y'all!

section 20

MODERN MATERIALS HANDLING THE FOUR-LEGGED CONCEPT

by **JOHN W. LAY, JR.**
Regional Engineer
RAPIDS-STANDARDS CO.

After receiving his Bachelor of Industrial Engineering degree from Georgia Tech in 1950, Mr. Lay joined Mechanical Handling Systems, Inc. (MHS) of Detroit.

While employed by MHS, he graduated from a three year training course in conveyor engineering in 1953, then worked as a salesman for a year before coming to Atlanta to open and become District Manager of the Atlanta Sales Office serving seven southeastern states.

In 1958 he resigned from MHS to become Chief Engineer for IMC, Inc. Then in April 1959 he joined the Rapids-Standard Co., one of the factories represented by IMC, as Regional Engineer.

His work for the past nine years has been in the fields of materials handling, plant layout, and methods. Mr. Lay has been involved with the application, design, sales, fabrication, installation, and maintenance of materials handling equipment in excess of $1,000,000 for warehousing, processing, and production plants.

Mr. Lay is a member of AIIE, National Society of Professional Engineers, and the Georgia Engineering Society.

MODERN MATERIALS HANDLING — THE 4-LEGGED CONCEPT

by John W. Lay, Jr., P. E.

Regional Engineer, Rapids–Standard Co., Inc.

TODAY aggressive business management demands greater operating efficiency to offset rising costs and to help maintain or improve profit margins. You have heard it before, and it is still even more true today, that one of the greatest opportunities to increase efficiency and cut costs, lies in improved methods of materials handling.

With this in mind, we as materials handling engineers would like to give you a concept with which it might be easier for you to take advantage of these opportunities.

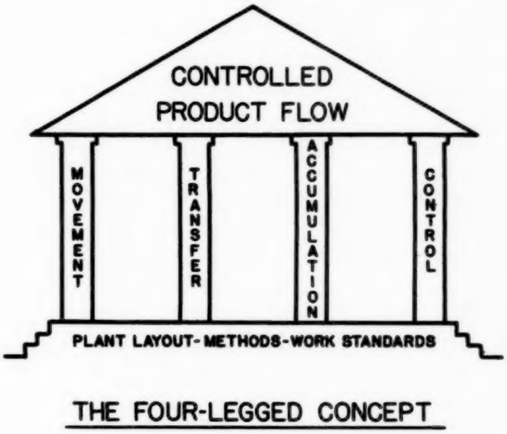

Figure 1

You will note from our chart here (Figure 1) that Controlled Product Flow is the result of several functions of Industrial Engineering:

1. Plant Layout
2. Methods
3. Work Standards

and the proper concept of the four materials handling functions:

1. Movement
2. Transfer
3. Accumulation
4. Control

Each of you have some background and experience in Industrial Engineering or you wouldn't be here at this National Conference.

So with this foundation, the understanding and use of our "4-legged concept" of materials handling should be easy.

All materials handling activities, whether they are in a giant industrial structure, such as Lockheed at Marietta, or in a local district warehouse in your own area, can be broken down and classified in one of these four categories.

Why break them down? Among many reasons, two good ones pertinent to our understanding here are:

1. Certain types of new equipment have been specifically designed to be used in one of the four categories and may not work at all in any of the other three.
2. In trying to utilize some of the newest ideas I will cover later, your ability to associate your present operations with these four categories should help you get started sooner in materials handling cost reduction programs for your own plant.

So let's start our classification with the simplest form of materials handling.

MOVEMENT

By definition, movement is the art of moving something from one place to the other, either horizontally, on an incline, or vertically, or combination of all, on many types of handling equipment.

In our concept, however, we must add the word "CONTROLLED" to MOVEMENT. Controlled Movement means more than the simple premise that materials must move. They also must move *safely,* reducing damage to the materials moved and minimizing hazards to operating personnel in the area of movement.

Examples of equipment used to achieve Controlled Movement would include all known types of conveyors, cranes, monorails, and trucks—when properly applied and used with the proper safety accessories.

Because most of you clearly understand this phase of our 4-legged concept, let us go on to the next.

TRANSFER

We all know that a straight line still is the shortest distance between two points. But how many materials handling problems are solved by a straight-line system alone?

In most stores, plants and warehouses, materials being handled usually must change DIRECTION. They go from floor level to floor level, around corners, over obstructions, down to a machine.

Materials may also undergo a change of CONDITION where they are halted in movement—from movement to storage, for example.

In addition, they also may change MEDIUM, from one type of equipment to another—conveyors to cranes, for example.

Therefore, a definition of TRANSFER might be: to move something from one piece of equipment to another, usually changing direction at the same time.

Transfers are probably the most difficult type of problem we as material handling engineers have to solve. A chief engineer in Detroit once remarked to me that figuring out what kind of conveying medium the material best moved on, was simple—but the problem of getting it on and off the conveyor was what made men out of conveyor engineer trainees—and he was right, as I later found out.

The number of different types of transfers would be almost infinite, limited only by the hundreds of different types of equipment to be connected together by such transfer devices.

In most cases, the word DEVICE more normally suits TRANSFER Equipment than any other. To take into account the difference in material handled, the originating equipment and the equipment receiving the material, a transfer most often winds up as a drafting-board DEVICE, designed either from scratch or modified from some known standard.

Since most Industrial Engineers don't have the time or perhaps the inclination to really get involved in such design work, one of our factory associates has come up with a group of data sheets on transfers for your use.

While they cover only 42 different transfers, each is shown in simple sketch form with advantages and limitations for your guidance. I emphasize that these 42 will not cover by any means all of the most widely used types of transfers. But they will give you a basic foundation for further work on your own and in cases, may even answer completely your questions, "Will my material transfer on this equipment satisfactorily?"

These data sheets will be available to those who want them a little later.

ACCUMULATION

We now come to the 3rd pillar of support for controlled flow—ACCUMULATION.

Of them all, Accumulation probably presents the greatest opportunity for Industrial Engineers to really improve their flow of material.

To understand this, let's review a little.

Accumulation in the past has always been "move, stop, then go." The "stop" part was usually a pile, be it neat or disorderly.

From the earliest times, American industry has been making piles of something, and it is possible to still find piles today in every plant. In addition, the pile is usually found where the pile has no business being. Why? Because it is usually piled there for *convenience*—a convenience at the time, but a costly mistake as far as controlled flow is concerned.

Now recently we woke up to the fact that some form of pile control had to be devised. We had to have controls as to the size of the pile and most important as to the placement of the pile.

This awareness has brought on use of new terms —"inventory control, mechanized inventory control, decentralized storage, inventory at point of use", also the term "accumulation lines" or "storage accumulators".

What is an accumulator? An accumulator is something affecting a change of condition in which goods are stopped temporarily and "contained" in the most efficient manner.

THE SILO

A simple example is a silo on the farm. It has been in use for decades, which is a whole lot longer than we have been aware of its application in industry.

It stores temporarily, using the cube principle in an efficient manner. What makes it efficient? It keeps the material on the move as all accumulators should do.

I don't mean to say that we ought to all start using silo-type accumulators. What I am saying is that we need to keep in mind the use of the CUBE, storage on the move, and the simplicity of the silo in devising accumulators for our own operations.

But first before we even start on accumulators, let's think if we can find a way to eliminate the *need* for them.

One thing that I guess I will always remember about my training program in Detroit was some of the philosophy of this same Chief Engineer I mentioned before. Hard to get along with in some ways, he was wise in many others.

After working on a particular engineering problem for some days in his department, I went to see him to report on my somewhat slow progress. He proceeded to convince me that trainees were surely meant to make him retire at an early grey-headed age and then in an almost fatherly way said this: "Before you try to solve any problem, always try to *eliminate* it first." *He did, and I'm still trying.*

And I suggest you try to eliminate most of your accumulator problems by eliminating the *need* for accumulation.

You may say this sounds good—but it's tough to do, and I'll be the first to agree.

However, remember this: Most plants are like fat people—you've got "inventory" in the wrong places. Just like fat, it slows down your material movement and decreases efficiency in all operations.

ACCUMULATION CHECK-POINTS

Let's review some check-points for eliminating the need for accumulators in receiving and in-process areas first:

1. Reduce the points of accumulation by putting the material where it is going to be used, the first time you handle it—commonly called the POINT OF USE CONCEPT in manufacturing processing.

How do you do it? Start with what comes in the back receiving door and find a way to buy on long-period purchases, with short-term periodic delivery, in containers you can handle efficiently, and quantities you can place at the point of use efficiently.

You can't do it? Ask Mark Balkcom here. A good part of his plant makes school goods that he has to worry about storing for his customers until the customers need it in one splurge. Most candy manufacturers are the same way. Probably even you do the same for your own customers.

So why can't you go back to *your* suppliers and work out a way to let *him* warehouse *your* material? Can you think of a better way to eliminate the need for accumulation?

It can be done, as the fellows from the General Motors Assembly Plant here will tell you. They don't accumulate more than 48 hours' material production requirements in almost all items they receive from their suppliers. So when you talk to them about accumulators, they don't have enough material to even worry about accumulating—EXCEPT—at the point of use, right on the assembly line.

2. Move that fat around—make sure the accumulation you have to have is in the best place. Remember that whether on a mass-production line or in a piece-rate job-shop, three things must be guaranteed for efficient production:
    a. A guaranteed source of supply of material.
    b. A balanced sequence of operations.
    c. An assigned, always available depot for finished work.

This means the best place to put the material in the first place is at the point of use for the next operation.

3. Eliminate the paperwork that helps to support the fat. Start again with the supplier. Make his shipping tags do the job of keeping up with your inventory in process. Why write up receiving reports and accumulate on the receiving floor while you do it, when by revising your paperwork system, you can eliminate the accumulation by eliminating the necessity of writing that report to begin with?

So far, all I have covered in regard to accumulation is that concerned with *receiving* and *in-process material.* Later, I have some photographs and slides to show you of how one plant followed these check points to the letter and how much it paid off.

ACCUMULATION IN WAREHOUSING AND SHIPPING

The other phase of accumulation to be looked at with the greatest of optimism for cost saving is in the warehousing and shipping end of your business.

Here you have the problems you just handed your suppliers a few minutes ago. We find that you are catering to your customer to hold his business any way you can.

The textile warehouse will package a great variety of small-volume items for a customer, tag the carton and then set it on the shelf for six months to a year, if necessary, before shipping it overnight at customer request.

The food warehouse will break a case and send out four bottles of vanilla if that's what the salesman could sell his customer.

The problem is universal—solving the problem is not. One way would be to set up a distributor as the caster manufacturers do. They eliminate the accumulation of odd-size lots by selling full cases to their distributors and let them worry about the order for one or two of a kind six months apart.

Assuming you aren't in a business that can be changed that way, then let's get to that accumulated storage problem another way.

THE VENDING MACHINE

Most warehouse accumulation can be looked at as a simple vending-machine operation. You fill up each magazine with products of one kind and gravity-dispense them one package at a time, the variety according to the shipping ticket—that silo principle again!

However, the chances are great that your warehouse doesn't even approach this principle. You probably are resorting to some form of *pile* again, by accumulating cartons on pallets, maybe pallets in racks, pallets on pallets, or maybe just cartons on the floor.

In every case, the package or container doesn't move closer to the shipping dock until *it gets moved* by something else—a manual transfer or a mechanical one with a lift truck.

If you are picking up an order or filling a shipping ticket, you probably are walking or riding four to six feet to pick one to two items. And after you pick the item, you accumulate it again on a four-wheel truck or lift-truck pallet.

Finally, when you finish the order you accumulate the order on the floor, or on the pallet on the floor, and write out a shipping bill of lading.

After all these accumulations, the carton finally gets into the truck or car and is accumulated again. No wonder we have staggering quality control problems—all these accumulations certainly don't reduce the chances for damage!

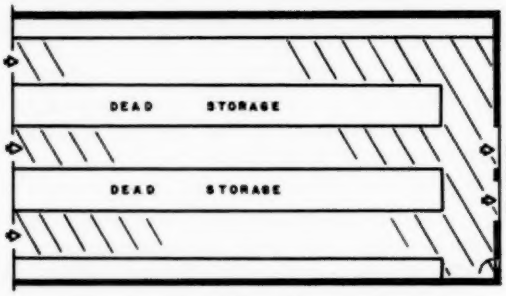

Figure 2

"Pile" Storage—50% Space Utilization—Long Selection Walk

In addition, we have probably wasted 50% (See Figure 2) of the total space set aside to store our products because we have to use that much for aisles, to be able to accumulate that many times!

Makes sense?

BACK TO THE SILO

If you agree with me that it doesn't, then let's go back to the silo principles again.

Suppose we take standard gravity conveyor equipment and tilt it to a level to produce movement of our cartons when placed on them. Or we go one step further, and place the pallet on gravity equipment to induce pallet movement.

We take advantage of the silo's cube by putting up layers or decks of this equipment, making the width and depth of the cube to suit the number of cartons or pallets to be stored.

The silo has now become the vending machine.

As with the vending machine, the magazine for each kind of product is filled, or available for filling full time. No aisles are necessary except at the back to fill the magazine and at the front to dispense the product (See Figure 3).

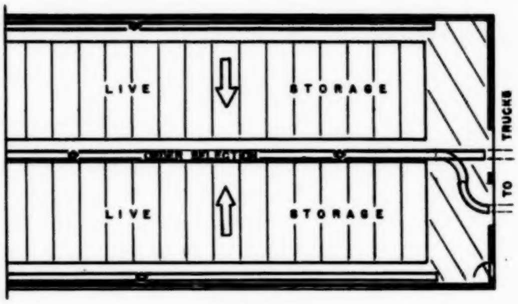

Figure 3

"Live" Storage—76% Space Utilization—Short Selection Walk

Now *nine or more* items are available for selection in the same walking distance *one or two* items were before.

We dispense the product onto a movement conveyor and it travels directly into a truck or car for that inevitable final accumulation. The shipping bill of lading was typed days ago when the order came into the sales office, one typing doing the job along with several others for interplant movement and accumulation, accounting, etc.

This is not the automatic push-button warehouse you hear rumors about, but just a simple inexpensive controlled flow accumulator system with a manual or mechanized transfer into and out of storage and conveyorized movement into the shipping medium.

There are other ways of doing this type of mechanical accumulation than with gravity. Power and free overhead carriers can be accumulated in spur lines; live roller conveyors can accumulate in the same manner as gravity equipment; friction chain conveyors can also be used to accumulate. Tow lines with trucks, roller flight conveyors, automatic dispatch monorails with carriers, and others are also used.

The principle of accumulation is still the same—keep it moving, use the cube, and keep it simple.

POTENTIAL OF ACCUMULATION

As you can tell by the last few minutes of talk from me, this subject of accumulation is one that has the materials handling industry in a race for "know-how." We see more possibilities for this type of equipment than any we know of right now.

It's a concept that can be utilized by every one of you, no matter what the size of your plant or business may be. On the other hand, to make the most progress, you are going to have to work with more people in more departments and encounter more resistance to change in paperwork, than on any other project you may have ever undertaken.

But since we have only an hour here in this session, I'm going to have to omit details of other very important considerations such as container standardizations, perimeter storage and automatic order selection. In some of the slides later you will see more applications in these areas.

I might add that there will also be available later to those who want it, a booklet entitled "The Technics Story." In this there are reprints of various magazine articles that have been written about the proving ground for this accumulation concept, complete with photographs of actual equipment and ideas in plant use.

CONTROLS

Last, we have the controls to make all of the other three functions of movement, transfer and accumulation work together to give us our desired controlled flow.

Controls are the key to the automatic plants and warehouses of tomorrow and the future. But saying controls means much more than pushing a button and seeing something happen, which is our most common understanding today.

To properly understand controls, let's define the three things that relate to the control function—brawn, brain, and intelligence.

BRAWN

The brawn is identified as the mechanical means of moving, lifting and transferring materials from one place to another. Brawn has to be controlled to the extent of providing safety and reliability, such as the proper degree of pitch on gravity accumulation lines.

BRAIN

The brain is identified as a function of control that can make simple decisions repeatedly. These simple decisions are of the "yes or no," "do or don't," "either-or" variety. An example would be the use of a single electrical limit switch to indicate that a carton is present or not present physically where the limit switch is located. The same would be true of electric eyes. Even most automatic dispatch overhead or floor line systems operate in this manner. The carrier flag or electrical circuit will be identified by each switching station as "either" the carrier belongs there, "or" it doesn't—all a "brain" function.

INTELLIGENCE

Intelligence is that function of control that requires judgment—a human-like function. It requires additional information fed into either mechanical and/or electrical devices to change the either-or, yes or on, do or don't decisions of the brain control.

One good example shows how brawn, brain, and intelligence work together.

Take a mechanical robot that can be directed to do a certain job. Suppose we direct him to reach across the stove and take up a pan that is on one of the burners. He will do just that, with the brawn strength he has available.

Suppose we install in his hand a heat sensitive device that says, "If the pan is hot, put it back down." Then he will reach out, grasp, feel the heat, and ungrasp, over and over until the pan cools beyond the temperature range of the heat device in his hand. Actually the heat device was a brain-type control, making "yes or no" decisions.

If the pan did not cool, the robot would never perform his job of picking up the pan.

But suppose he had intelligence control. With the heat information fed to his brain equipped with judgment functions, his orders would be altered to: "Move away from the pan, pick up a pot holder to insulate the heat device, and then pick up the pan," thereby accomplishing his mission.

Remembering how brawn, brain, and intelligence work together, you can begin to understand how far you have to go to automate completely any operation or plant.

MANAGEMENT CONTROLS

In addition to controls as related to materials handling equipment, part of the intelligence required to automate comes from management itself.

The paperwork function is just as important to intelligence as the equipment function is.

We have already found even on installations requiring some brawn and a little brain, that until the paperwork was modernized to go along with the brain control, the entire system failed to pay for itself as it should.

Controls are not as complicated as they sound really, once you have in mind these three phases of controls. We always try to use all the "yes or no" decisions possible with $15.00 limit switches before trying to work in intelligence equipment at costs that go into orbit pretty quickly.

As I understand our schedule this afternoon, more information will be available to you later from experts in this intelligence field, through the data processing equipment people themselves.

PROOF OF THE CONCEPT PUDDING

Now that we have briefly covered this 4-legged concept, let's take a look at what one small job-shop type business accomplished when they put to use all the facets of the concept:

1. 40,000 sq. ft. of floor space was gained within the existing plant with an investment of $100,000, eliminating a planned $300,000 building program.
2. Inventory was reduced by $100,000 through gearing of purchasing policies to the new warehousing accumulation concept.
3. Productive capacity was increased by 50% without the addition of space, manpower, or manufacturing machinery.
4. 8,000 additional sq. ft. were released from manufacturing for finished goods storage, enabling sales to offer better shipping dates on more stock items.
5. Additional office space was created for a 100% increase in sales engineering personnel, enabling the company to give still better service in markets formerly impossible for them to cover.

They say the proof of the pudding is in the eating. This pudding has tasted mighty good to this company and gets better as they continue to "taste" it!

For those of you who are interested in learning more about what was actually done and how it was done, we will have available later this booklet, "The Technics Story."

In the meantime, let's take a look at some slides and photographs illustrating applications of this four-legged concept as we now know it.

WORK SAMPLING AS APPLIED TO SIMULATION

by **CHESTER L. BRISLEY, PH.D**
Staff Assistant to Director of Production
CHANCE VOUGHT AIRCRAFT, INCORPORATED

MR. BRISLEY received his B.S. in I.E. in 1939 from Youngstown University; his M.S. in I.E. and Ph.D. from Wayne State University in Detroit, Michigan.

From 1935-1942 he worked at Packard Electric Division of General Motors at various jobs such as Inspection, Cooperative Student, Cost Accounting and Industrial Engineering.

From 1942-1945 he was Supervisor of Job Improvements and Supervisor of Time Standards at North American Aviation at Dallas, Texas.

From 1946-1958, he was employed as Industrial Engineering Supervisor and later as Industrial Engineering Manager at Wolverine Tube, a Division of Calumet & Hecla, Inc.

Mr. Brisley is currently Staff Assistant to the Director of Production at Chance Vought Aircraft in Dallas, Texas. He is responsible for Work Simplification, Work Sampling, and Operations Research in the Production Organization.

He is a member of the Industrial Management Society, Operations Research Society of America, American Management Association, and American Statistical Association as well as the American Institute of Industrial Engineers, Inc.

He has presented training programs and talks at many Universities and before numerous professional societies; likewise, he has written many articles on Industrial Engineering.

WORK SAMPLING AS APPLIED TO SIMULATION

by Chester L. Brisley, Ph.D.

Staff Assistant To The Director of Production
Chance Vought Aircraft, Incorporated

BY THIS TIME Industrial Engineers are acquainted with work sampling, or the ratio delay technique, which has been in use since 1927 when L. H. C. Tippett introduced it. But what is simulation? Is simulation something new or have we been using it for years under a different name? The answer to this question is: Yes and No. Under the "Yes" answer, Industrial Engineers have for years made use of models but have called these models by a different term such as: "flow charts," "man-machine charts," "micromotion study analyses," "plant layouts" (both 2 dimensional and 3 dimensional), fatigue studies, "surveys," "time-studies," "cost analyses," and "work sampling studies." These models can very effectively be a part of simulation. Examples of simulation in industry are the wind tunnel in aircraft plants, the pilot plant, model layouts, etc.

However, new tools are demanded in our new world of automation, computers, and the space age. The tools of the past have been limited to two or three parameters. Simulation often requires that a mathematical model become a part of the system to be simulated. This is where the old time I.E., who has been out of college a few years and has forgotten much of his mathematics, steers away and decides that he is not interested in this more advanced stage of industrial engineering. Nevertheless, it behooves the more recent graduates in industrial engineering to train the old timers in the tremendous tools of Operations Research. Simulation is one of these tools:

> Simulation is the study of the effect that different policies, procedures, systems and competitive strategies have upon the outcome of a complex plan or endeavor.
>
> Simulation is a management tool that can be used as:
>
> A training method.
> A problem solving method.

Today we are going to explore both aspects of simulaton as it concerns the work sampling techniques.

Don Malcolm, whom most of you know, for he is a past national president of the AIIE and until recently affiliated with Booz, Allen, and Hamilton as the Director of Operations Research, gave us at Chance Vought an assist in the use of this problem solving approach.

SIMULATION: A TRAINING METHOD

Games are as old as man. Usually their basic objective is entertainment. The military services have been using war games for years. The military games and the Business Management games, introduced by both the American Management Association and McKinsey & Company, aim not at entertaniment but at learning.

Business games are the first promising attempt to provide management personnel with experience in business problems by simulating the real-life operations of a business.

If any business game is to serve a purpose beyond that of entertaining, there must be some transfer of learning from the game situation to reality.

As a training tool, we have prepared a work sampling demonstration of an office situation. Through simulation the process of acquiring experience is speeded up.

By stripping away nonessentials, the game in which we are about to participate makes it possible to simulate five days' work sampling experience in approximately 20 minutes.

Perhaps it would be well to again define work sampling:

Work Sampling is a method of measuring work by the use of instantaneous random observations. The greater the number of observations, the greater the accuracy. With the aid of this film, Work Sampling may be demonstrated.

FILM DESCRIPTION

The film shows a clerk writing orders in the Production Order & Release Group of Chance Vought. It comprises 240 scenes simulating five days of work sampling observations. As the order writing activity, along with the necessary activities of filing, walking to and from files, and receiving instructions, takes place the day and the time of day will be narrated on the film. For example, the first scene is Monday 8:00 AM, the second Monday 8:10 AM, next 8:20, 8:30, 8:40, 8:50, 9:00, 9:10, etc. for the first day. An hour is allowed for lunch from 12:00 noon to 1:00 PM each day. These times are heard as the scenes are observed. After 5:00 PM is called, the next day begins "Tuesday 8:00 AM, etc. and this narration continues for the five-day week, Monday through Friday.

AUDIENCE PARTICIPATION

Each person participating in the demonstration should have a Work Sampling observation sheet and a copy of introductory comments. The entire operation of order writing has been divided into five activities as follows:

1. Order writing
2. Filing
3. Walking
4. Receive instructions
5. Idle

These are listed on the observation sheets, of which there are twenty different forms. Each of the twenty forms has a different set of random times. Each person participating in the demonstration should make a tally mark at the instant each time is called that is on his work sampling observation form. Each person participating will record on a random basis 12 observations for each day or 25% of the scenes. At the end of the simulation study he will have observed 60 out of the 240 scenes.

(Project Film*)

With only 60 observations the individual margin of error may be quite large. Using element "Order Writing" as an example, the percentage of "Order Writing" as determined by a thorough film analysis is 52.5%. Therefore, it is reasonable to expect an individual observer to get as high as 59.6%, or as low as 45.4%. We shall carry the demonstration through by showing how as you compile the percentage of element #1 and add 60 observations from one person and 60 observations from another and thereby accumulate the number of observations to 600, the accuracy of the resultant percentage more nearly approaches the true figure.

(The group will plot on the Upper and Lower Control Limit Chart furnished with the Observation Sheets, the percentage results of each of ten members of the group for Element No. 1 "Order Writing". Therefore, the percentages of Element No. 1 from 60 to 600 observations are plotted.)

ENDS OF SIMULATION WITH RESPECT TO TRAINING

Since according to our definition:

Simulation is the study of the effect that different policies, procedures, systems and competitive strategies have upon the outcome of a complex plan or endeavor.

What is the effect brought forth by this demonstration film?

We have simulated through this film the work sampling method. Therefore, we are receiving training in this approach and the training method of simulation has been demonstrated.

SIMULATION: A PROBLEM SOLVING METHOD

Now how is work sampling applied to simulation?

In this study we have established 5 activities or 5 parameters of which we have determined a high degree of accuracy for one parameter.

As a problem solving method simulation depicted in this film portraying the following parameters were pinpointed by work sampling:

TABLE 1

Percent of Office Work Sampling Activities

%	Activity
52.5	Order Writing
12.5	Filing
15.0	Walking
9.6	Receiving Instructions
10.4	Idle

In a simulation study depicting problem solving we propose to do the work of the "Order Writing" clerk on paper. This requires that all of the facts be included in the simulation study to obtain an accurate and realistic simulation. As you will see as we proceed with this simulation study, some of the facts are supplied by the work sampling study, and some are supplied by time study and by other industrial engineering techniques. To ascertain that the simulation is accurate, it is important to carry on the simulation for a period of time and compare it with the parameters established through work sampling. Therefore, it is first necessary to diagram the system (See Figure 1).

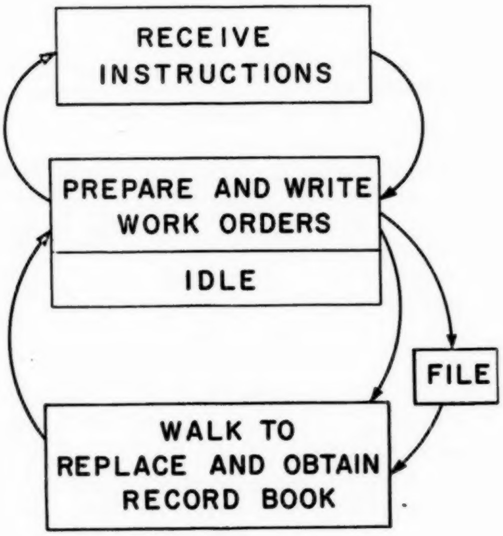
RECEIVE INSTRUCTIONS
PREPARE AND WRITE WORK ORDERS
IDLE
FILE
WALK TO REPLACE AND OBTAIN RECORD BOOK

Figure 1

Diagram of Simulation of order writing activity

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*This film may be purchased at cost or borrowed by writing the speaker. (After the demonstration has been completed.)

SIMULATION RECORD

It is necessary to establish the activities of the Order Writing Clerk each minute of the day, Monday through Friday. The facts gathered through time study and work sampling enable the Industrial Engineer to set up the simulation study. The most common way to do this is to program a computer. However, to simplify the explanation of this simulation I am using a different approach whereby the simulation may be carried out on paper.

Prior to starting the study, we develop a Simulation Record (Figure 2).

Time of the Day	NUMBER OF MINUTES					Number of Orders per Record Book	
	Idle	Writing Orders	Receiving Instructions	Filing	Walking	No.	Total

Figure 2

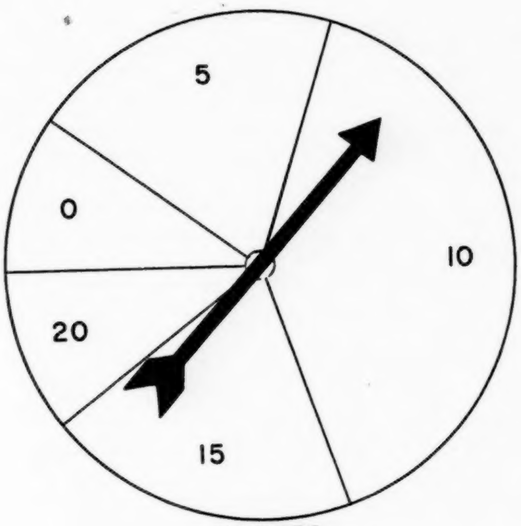
Simulation Record

IDLE TIME—AT BEGINNING OF DAY

To start the simulation, let us suppose that it is Monday morning at eight o'clock and the clerk, seen in the film and the one whose work we are to simulate, is seated at her desk. Our experience indicates, as shown in the film, that her most likely activity at this hour of the day, each day of the week, is to be idle. The length of time she is idle varies from one day to another—twenty minutes idle one day, zero minutes idle another day, ten minutes idle the next, etcetera. We start, then, by letting chance decide a length of time for idle, we spin the spinner in Figure 3. We tabulate the result of this spin (the number of minutes) on the Simulation Record in the column marked "Idle".

NUMBER OF ORDERS

The next activity is to get a record book. The clerk must leave her desk for this activity, walk to the file, remove the proper record book and walk back to her desk. The time required to obtain the record book is one minute. We tabulate one minute on the simulation record in the column marked "Walking".



MINUTES
Figure 3

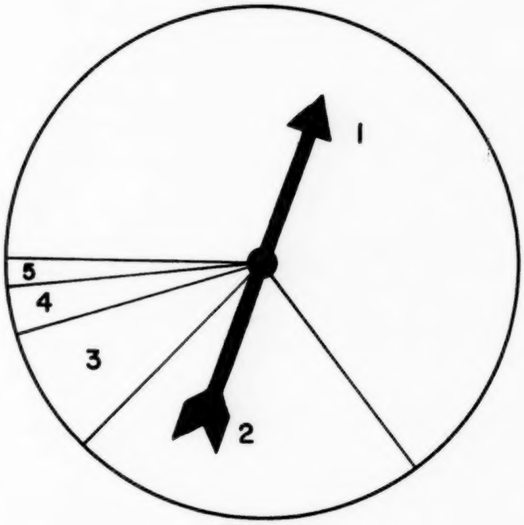
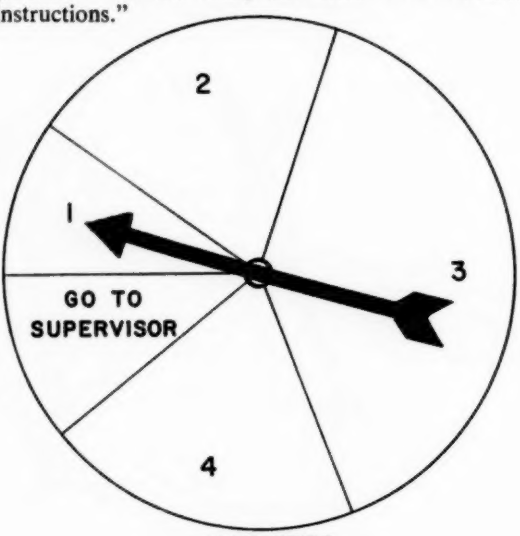


Figure 4

The number of orders that may be written with this record book is not known. One or two orders from a single record book is the more common occurrence, although occasionally as many as five orders may be written from one record book. Since the number of orders is not known, we let chance decide the number, we spin the spinner in Figure 4. We tabulate the result of this spin on the work sheet in the column marked "Number of Orders".

COMPLEXITY FACTOR

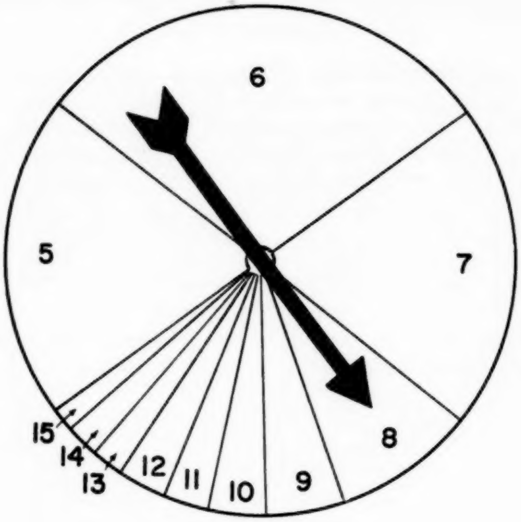
The time required to write each order is variable. We know that one minute is required to fill out standard entries in the order, such as the due date, part number, quantity ordered, authorization number, etc. The time required to complete the order—beyond the one minute—we attribute to a complexity factor. (The clerk's thinking, planning and calculating.) The complexity factor reflects the difficulty of scheduling the parts to be manufactured under the order. This complexity factor varies with each order and the time required varies from one minute to four minutes. Since the time required to complete each order due to the complexity factor is not known, we let chance decide the number of minutes, we spin the spinner in Figure 5. We tabulate the result of this spin, plus one minute, on the Simulation Record in the column marked "Order Writing". We continue our simulation of order writing by repeatedly spinning the spinner in Figure 5 for each order until all of the orders that may be written from this record book have been completed. The time is recorded on the work sheet after each spin as "Order Writing" unless, by chance, the spiner should stop on "Go To Supervisor". In this case, the clerk is to "receive instructions."



MINUTES
Figure 5

RECEIVING INSTRUCTIONS

The time required to receive instructions is decided by spinning the spinner in Figure 6. Five to fifteen minutes may be spent in "receiving instructions"; however, five, six, and seven minutes occur most frequently. If "Go To Supervisor" should occur, we tabulate the one minute required of all orders in the "Order Writing" column, we tabulate the time to receive instructions in the column of the work sheet marked "Receiving Instructions," and we arbitrarily tabulate two minutes in the "Order Writing" column to complete the order after receiving the instructions.



MINUTES
Figure 6

After all the orders that are to be written from this record book are completed, we replace the book and obtain another by tabulating one minute for walking. We repeat the process as outlined above by choosing:

(1) The number of orders that may be written from the record book,
(2) the time required to write each order,
(3) the time required to receive instructions,
(4) tabulate the results on the Simulation Record.

IDLE TIME—DURING MORNING AND AFTERNOON

We may repeat this cycle—from record book to record book—as many times as we should like. However, as we continue this simulation, cycle after cycle, we realize that certain details have not been considered. We have not allowed for idle time during the morning or before lunch, nor have we stated any rules to terminate the simulation at 12:00 o'clock to permit the clerk to eat lunch.

To assist us in these details, we keep a running total of the time spent in the various activities in the column of the work sheet marked "Time of the Day". Experience indicates that when the time of the day is between 9:30 and 10:30 and when an order has been written or a record book returned, we should expect idle time to occur. We include this chance of idle time in our simulation by spinning the spinner in Figure 3 once, and only once, between 9:30 and 10:30 after an order has been written or a record book returned. We enter this idle time on the work sheet and then continue writing orders, walking or receiving instructions.

At about 11:30 we will interrupt our activities to spin the spinner in Figure 3 for the idle time that is expected to occur before lunch. We tabulate the result in parenthesis of this spin on the work sheet in the column marked "Idle Time". This idle time is only a first guess of the time we will actually use because it may be modified by the following rules.

Rule 1—If our choice for idle time before lunch is *not* zero, an order that has been started before the idle time is supposed to start is completed (this may reduce the idle time that we have chosen as the first guess by as much as four minutes).

Rule 2—If our choice for idle time before lunch *is* zero, then if we are writing an order when 12:00 o'clock comes, we just stop, go to lunch, and complete the order after lunch.

Rule 3—If "Go To Supervisor" should occur while we are writing an order, and if we do not have 15 minutes left before the lunch hour, we will wait until after lunch to receive instructions and either be idle until the lunch hour or write other orders (if we do not have to obtain a new record book).

We start the afternoon the same way that we started the morning: Choose an idle time. After the idle time, we complete the activities that might have been started in the morning but were not finished. Our simulation for the afternoon follows the same process that we have outlined to describe the morning. We expect idle time to occur in the afternoon between 2:30 and 3:30 o'clock, and we follow the same three rules, above, to stop our simulation at five o'clock. We simulate the work of the clerk on Tuesday just as we have for Monday, and so on for as many days as we wish. We must remember that those activities that were started but not completed one day must be completed the first thing in the morning (after idle time) the next day.

FILING

The activity "Filing" has not been included in our simulation, as yet. The purpose of this activity is to obtain the actual material that is needed to write each order. When sixty-six orders have been written, the clerk must go to the files (one minute walking), obtain the materials that are needed for the next sixty-six orders (filing), and return to her desk (one minute walking). The filing takes 60 minutes. Actually the clerk may obtain material for a number of orders ranging from 60 to 72 orders. The filing rate is 1.1 forms per minute. However, for simplicity in our simulation, we assume that the average number of minutes are needed for filing and that material for the average number of orders is obtained. On the work sheet, we keep a record of the total number of orders that have been written. When this total is sixty-six, we enter one minute walking to return the record book and go to the files, we enter 60 minutes under the column marked "Filing" and then one minute for walking to return to her desk.

This completes the description of the simulation-on-paper of the activities of the clerk in the film.

BENEFITS OF SIMULATION

We have presented two simulations, one describing work sampling and the other describing the order writing process of the clerk. The first simulation demonstrates a method of obtaining real and important information in a relatively inexpensive manner. The second simulation illustrates another more expensive method of obtaining information, that may not be important and is never real. The second method is synthetic, it is only a model of the real process. However, if our model is a sufficiently accurate representation of the real process, the model may be used in an attempt to answer questions such as:

How long will it take to process 1,000 orders?

What is the average cost to write 1,000 orders?

Could costs be reduced by assigning the walking and filing activities to another person?

We should like our model to be sufficiently accurate so that we will be able to answer these questions and many more. We might like to show how rush orders upset the routine and cause delay in the order writing process, to show how the process is slowed while a new clerk is being trained, or in general, we may wish to use the model as a means of evaluating many possible changes in the basic process before these changes are incorporated in the real process.

Our model of the process is not inexpensive, since, quite often, a good deal of research is required to develop the rules of the process and to obtain the information that is needed to construct the spinners. The experience of the supervisor, and the clerk, the results of time studies and of work sampling may reduce the research that is needed. Likewise, we may be able to devise new sampling methods which would add information needed for the model. Of course, if the information that is needed is not available, the supervisor, the clerk and the Industrial Engineer are needed as a team to collect the information before any model of the process is possible.

The cost of the model depends initially, on the amount of information that is available and the amount that must be collected so that we will have the accuracy that is desired. The accuracy is in turn dependent upon the importance and the complexity of the process. There is another cost, which should not be ignored, namely the cost of maintaining the model of the process once it is developed. We do not expect the process to remain unchanged over a long period of time. Must the clerk and the supervisor continue in the collection of information in order to maintain the model? No. They need only be available at some later date to modify some of the rules, or the spinners that are used in the model. It is at this point that we may show the relation between the model and the results of work sampling. One means of determining the accuracy of the model initially, or at any later date, before suggested changes in the process, or after they have been incorporated, is to compare the results that are obtained from the model with the results that are obtained through work sampling. Should the results disagree, we must ask for or search for new information to improve or modify the model. The work sampling results will tell us *when* the model is no longer accurate, in what *manner* it is not accurate, and the magnitude by which it is not accurate.

Comparison of Simulation and Work Sampling

We may illustrate the relation between the model and the work sampling results by considering the activity "Receiving Instructions". The clerk receives instructions 9.6% of the time or 46 minutes a day. This time is the average of the product of two factors in the model:

The number of trips to receive instructions.

The number of minutes—per trip—spent receiving instructions.

If at a later date we should find the percentage to be 5%, we would know the magnitude of the inaccuracy in the model but we would not know whether the number of trips to receive instructions had dropped or the number of minutes per trip spent receiving instructions, or both. A reduction in the number of trips might reflect recent training given to the clerk, while a reduction in the number of minutes to receive instructions might reflect recent simplification methods devised by the supervisor. A reduction in both the number of trips and the number of minutes may reflect recent modifications of the process.

MATHEMATICAL MODELS

There are three instances in our presentation in which mathematics is important. The first instance is in the theory of the application of work sampling. The mathematics for this theory is found in many articles and textbooks on work sampling and will not be repeated here. The second case where mathematics is important is in the theory of the spinners, and the third case is the model. It is the mathematics of the second and third cases that we wish to consider here.

Each of the spinners that we have used in our simulation represents a probability distribution function. Some well-known and widely used probability distribution functions are the:

Normal distribution
Binomial distribution
Beta distribution
Poisson distribution

The purpose of work sampling, mathematically, is to get an estimate of p in the mathematical expression of the Binomial distribution. In this case we know that the Binomial distribution is appropriate. What distributions describe idle time, time to receive instructions, number of orders per record book and the complexity factors? It is here that a great deal of information is needed to indicate the appropriate distributions and their parameters. It is here that the I.E. should consult the mathematician for assistance.

CONCLUSION

Simulation is a tool that should be in the kit of tools of an I.E. Like any other tool it has its place, but if used when a more economical technique will serve better, we will be glorifying an approach needlessly. However, where a great amount of experience is required to analyze a problem, simulation may be a very economical and expeditious way of solving a problem.

AUTOMATION - A CASE STUDY

by **H. R. BENTLEY**
Plant Manager
CHRYSLER ENGINE DIVISION — MOUND ROAD PLANT

After college, Mr. Bentley spent several years in the employment of consulting engineering firms engaged in municipal construction. In 1936 he became Public Works Superintendent for the City of East Lansing where he was employed for four years.

Mr. Bentley has been associated with Chrysler Corporation since 1942 when he joined the Evansville Ordnance Plant as Supervisor of Construction Engineering. Two years later he was transferred to the X-100 Plant (Division of Oak Ridge Atom Bomb Plant) as Chief Layout Engineer. From 1946 to 1955, he served successively as Chief Layout Engineer, Assistant Plant Engineer and on Special Assignment to the Staff Plant Engineer. In March, 1955, he transferred to the Engine Division as Assistant Plant Engineer, Plant Engineer, and Manager of Production Planning. He was appointed Plant Manager of the Chrysler Trenton Engine Plant in November, 1956. On February 1, 1959, he transferred to the Chrysler Mound Road Engine Plant as Plant Manager.

Mr. Bentley was born in Lapeer, Michigan. A registered professional engineer, he holds a bachelor's degree in civil engineering from Michigan State University.

AUTOMATION — A CASE STUDY

by H. R. Bentley

Plant Manager
Chrysler Engine Division, Mound Road Plant, Detroit, Michigan

PART I INTRODUCTION

A brief review of early types of "automated" industries followed by a discussion of the manufacturing problems which Chrysler's Mound Road Engine Plant was designed to solve.

PART II BENEFITS OF AUTOMATIC ENGINE MANUFACTURE

This section will be devoted to the most significant improvements obtained through automation at the Chrysler Mound Road Engine Plant.

- Increased Efficiency of the Working Force
- Reduced Scrap and Repair Costs
- Improved Product Quality
- Stabilization of Employment
- More Efficient Salvage Operations

PART III THE EFFECT OF PART AND EQUIPMENT DESIGN ON AUTOMATIC OPERATIONS

Mr. Bentley will describe those operations which proved most troublesome to operating personnel. Specific problems will be analyzed to illustrate the need for close liaison between Product Designers and Production Engineers.

PART IV AUTOMATION'S CHALLENGE TO MODERN MANAGEMENT

A provocative analysis of the problems involved in selecting, training, and motivating personnel in complex manufacturing facilities.

ADVANCED MATERIAL HANDLING TECHNIQUES IN PRODUCT DISTRIBUTION

by **JAMES M. APPLE**
Industrial Management Consultant

Mr. Apple organized and was in charge of the Industrial Engineering program at Michigan State University from 1947 to 1957. In the summer of 1957 he resigned as Professor of Industrial Engineering to enter the consulting field.

Mr. Apple is the author of the book *Plant Layout and Materials Handling,* the Plant Layout Section of the *Production Handbook,* and has written widely in the field of Industrial Engineering.

Although, practicing in the general field of Industrial Engineering, Mr. Apple specializes in Plant Layout, Materials Handling, and in the development of custom-designed training programs. He has performed consulting assignments for over fifty firms.

Mr. Apple is listed in Who's Who in Engineering, Who's Who in Education, Who's Who in the Midwest, and Leaders in American Science.

ADVANCED MATERIAL HANDLING TECHNIQUES IN PRODUCT DISTRIBUTION

by James M. Apple

Industrial Management Consultant

SCOPE OF MATERIAL HANDLING

UNTIL recent years, material handling was commonly understood to deal primarily with the movement of goods through a production facility—from work place to work place. Occasionally thought was also given to the storage and handling of the finished product.

Today, however, with the greatly increased quantities of goods being produced and with the attendant problem of their distribution over wider and wider areas—the material handling problem has mushroomed in proportion. Material handling, as it is presently conceived by its practitioners, encompasses *all* movement of materials—from source to consumer.

A CONCEPT OF PRODUCT DISTRIBUTION

It is fairly safe to say, then, that in the progressive industrial situation, material handling is considered in a much broader framework than it was only a few years ago. The modern material handling engineer considers not only the movement through his own production facilities, but visualizes his responsibility as extending back into those plants which furnish his materials and supplies, and forward—frequently into the hands of the ultimate consumer.

Why this sudden interest in the broader definition of material handling? Primarily one reason—cost! It is a commonly accepted premise, that material handling costs account for about 30-35% of the production dollar. In many cases, it is far greater than this. One authority states that the average plant handles 50 tons of material for every ton of finished product turned out. This is one way of saying that every piece of material is handled *50* times! And these figures are estimates! Many plants have *no* idea of the actual costs of material handling, because they are commonly considered as overhead items and are generally covered up in the cost accounting system.

However, it is realized today that material handling is a "goldmine" of cost reduction possibilities, therefore, the increased interest in material handling and its broader interpretation. This enlarged concept of the problem opens up even larger cost improvement areas. So, the modern material handling engineer begins to think of his handling problems as they may be *caused* by the way in which he receives materials. He also realizes that the over-all cost of product distribution is just as much affected by the costs incurred by his customers, which are in turn caused by how he packs his finished product. For these reasons, the material handling engineer works with his suppliers—to plan the way in which he wants to receive materials—for ease of handling. Likewise, he works with his customers, in planning packing methods to facilitate the handling activities of the customer. This concept is known today as an integrated material handling and packaging program, and when carefully studied and planned, offers tremendous cost reduction possibilities all along the line.

IMPLEMENTATION OF PRODUCT DISTRIBUTION

Much of the handling activity involves employee methods and mechanical equipment. Employee methods—or motion study—has long been practiced in the production phases of industry, and now looms as an important factor in similarly reducing handling and packing costs. Mechanical equipment is a correspondingly large factor in the over-all material handling problem. These two factors—methods and equipment—when combined in the proper engineering fashion, are the keys to cost reduction in material handling and product distribution.

Much of the handling equipment in use today is basically the same as it has been for many years. A high proportion of the new handling techniques are adaptations and combinations of basic equipment types that have long been on the market. A few are entirely new concepts in material handling. And a surprising number prompt one to ask, "Why didn't we do this before?"

With this background in mind, then, let us look at some of the newer and more unusual techniques being applied to modern material handling and product distribution.

EXAMPLES OF ADVANCED MATERIAL HANDLING AND PRODUCT DISTRIBUTION

For practical purposes, it seems advisable to classify the material handling techniques according to basic equipment types. It will be noticed, however, that many of the techniques cut across conventional equipment classifications, and combine two or more basic types, into an integrated system.

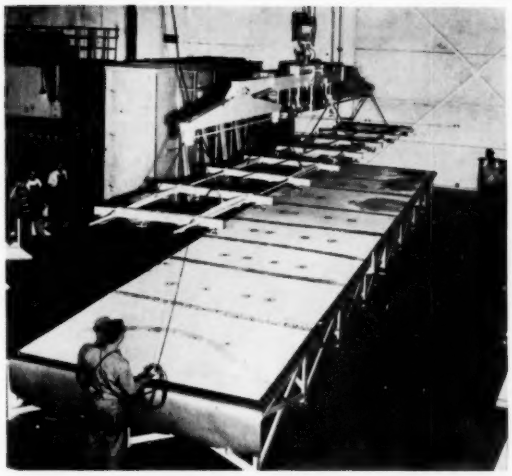
An Outline of Some Recent and Unusual Developments in Advanced Material Handling and Product Distribution:

(to be illustrated with slides and descriptive comments)

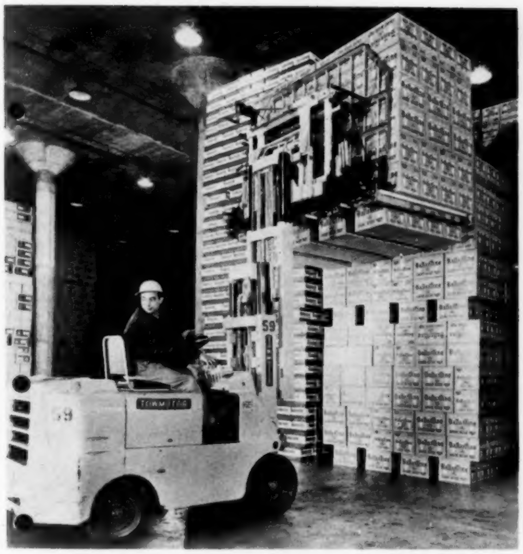
- I. Conveyors
  - A. Riverlake System
  - B. Monoflo Conveyor
  - C. Moving Sidewalks
  - D. Others
  - E. Trends
- II. Overhead Cranes
  - A. Trak-Rak
  - B. Vacuum Attachments
  - C. Others
  - D. Trends
- III. Industrial Trucks
  - A. Guided Trucks
  - B. Palletless Handling
  - C. Straddle Carriers
  - D. Attachments
  - E. Others
  - F. Trends
- IV. Containers
  - A. Rubber Balloons and Bags
  - B. Molded Containers
  - C. Unit Containers
  - D. Others
  - E. Trends
- V. Industrial Buildings
  - A. Air Supported Structures
  - B. Pre-Fab Structures
  - C. Dome-Type Structures
  - D. Others
  - E. Trends
- VI. Railroad Equipment
  - A. Bracing Techniques
  - B. Piggyback
  - C. Others
  - D. Trends
- VII. Air Transport
  - A. Unloading and Loading Techniques
  - B. Others
  - C. Trends
- VIII. Water Transport
  - A. Fishyback
  - B. Tow "Bags"
  - C. Others
  - D. Trends
- IX. Highway Equipment
  - A. Self Loaders
  - B. Adjustable Height Equipment
  - C. Tank Trucks
  - D. Unit Containers
  - E. Combinations ("Truckyback")
  - F. Others
  - G. Trends
- X. Storage and Warehousing
  - A. Rack Systems
  - B. Handling Systems
    - 1. Roller and Wheel Racks
    - 2. Slide Racks
    - 3. Control Systems
  - C. Palletizers
  - D. Storage Devices
  - E. Automatic Warehouse
  - F. Others
  - G. Trends
- XI. Miscellaneous
  - A. Magnetic Devices
  - B. Automation
  - C. Communications
  - D. Processing During Movement
  - E. Leasing
  - F. Others
  - G. Trends

CONCLUSION

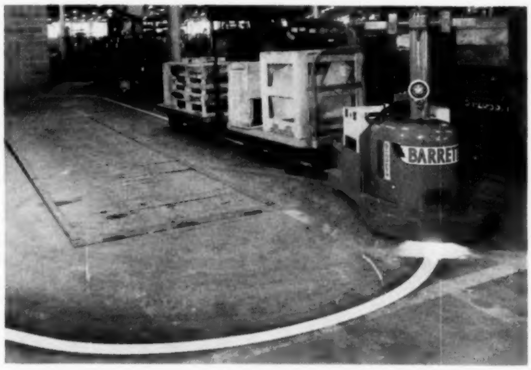
It should be evident from the discussion of the preceding installations and applications that much new thinking has been done in the field of material handling and product distribution. For a field of endeavor which is as old as the pyramids, the events of the past few years represent a vastly more rapid change of events than has been apparent in any other similar period. The obvious impetus to this development is, of course, rising costs. Industrial management which hopes to survive the present cost-price-profit squeeze must do similar advanced thinking in relation to its own problems. If material handling progress in your own plant has been no better than average, here's a chance to reduce costs in a phenomenal way. With such a large target to aim at (30-35% of the production dollar)—you can hardly miss. But—it will take top calibre thinking, careful planning, and good Industrial Engineering.



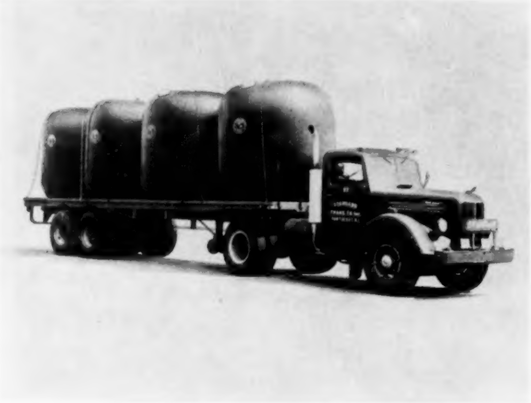
II. B-1 *Vac-U-Lift Aluminum Sheet and Plate Handler*


TOWMOTOR
59

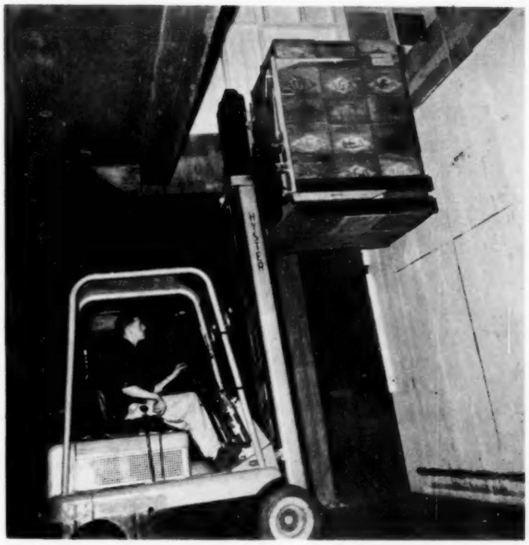
III. D-2 *Cartwright Lifting Forks*



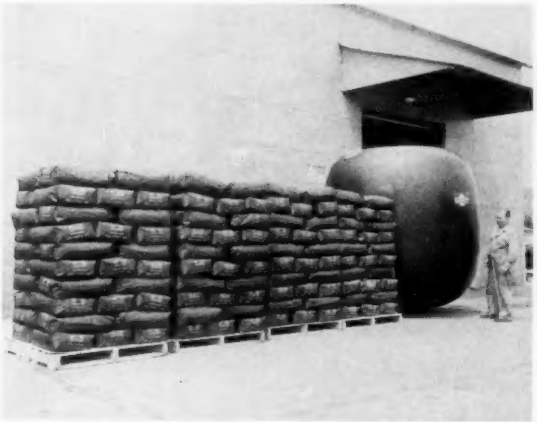
III. A-1 *Barrett Guide-O-Matic Tractor*



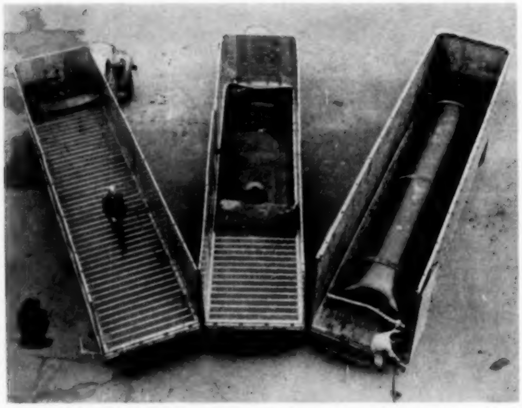
IV. A-1 *U.S. Rubber Sealdbin*



III. D-1 *Cascade Box Grab*

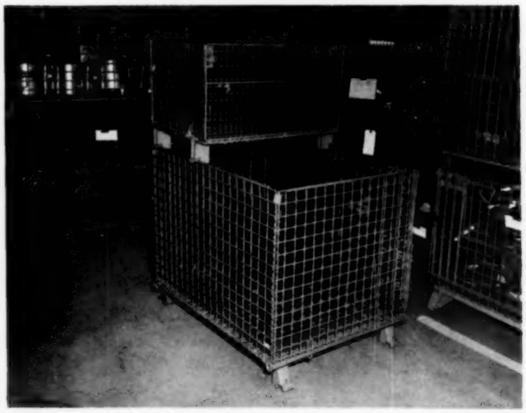


IV. A-2 *U.S. Rubber Sealdbin*

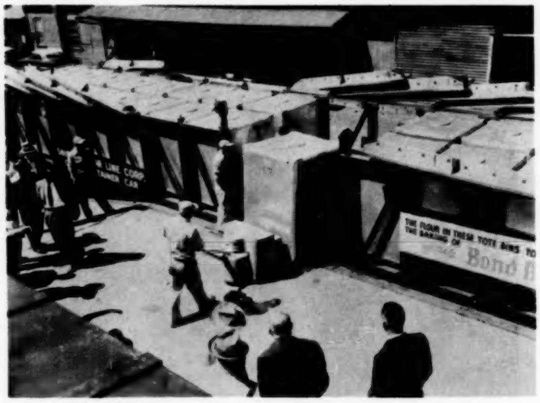


IV. A-3 *U.S. Rubber Sealdbin*

IV. C-1 *Union Steel Products Palletainers*



IV. C-2 *Union Steel Products Palletainers —Senior and Junior*



IV. C-3 *Tote System Containers*

V. C-1 *Union Tank Car Corporation "Roundhouse"*

V. C-2 *Metal Dome Building—Exterior*

V. C-3 *Metal Dome Building—Interior*

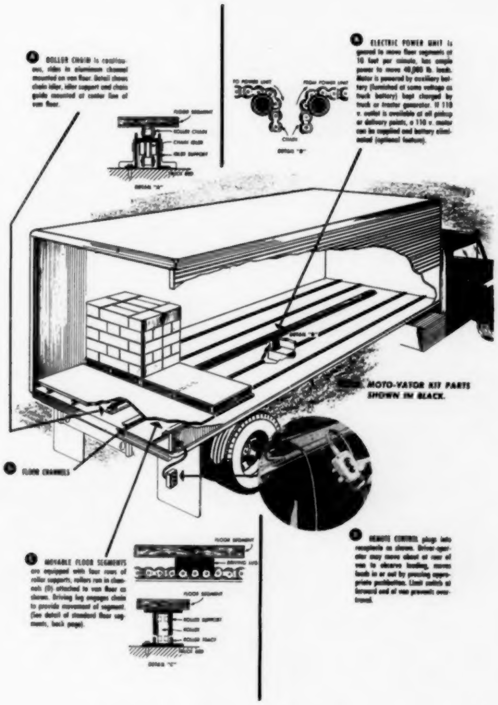
70484
0346 10

VII. A-1 *Lockheed Lightning Loader*

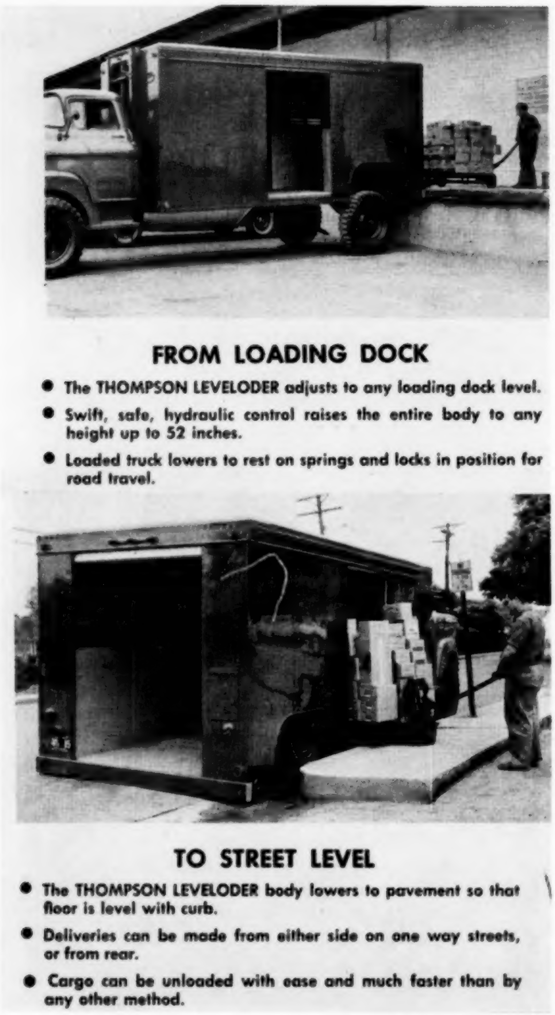
NEW YORK CENTRAL
NYC 500805

VI. B-1 *New York Central Flexi-Van*

VI. C-1 *United States Rubber Shor-Kwik*


A ROLLER CHAIN is continuous, rides in aluminum channel mounted on van floor. Detail shows chain idler, idler support and chain guide mounted at center line of van floor.
FLOOR SEGMENT
ROLLER CHAIN
CHAIN IDLER
IDLER SUPPORT
TRUCK BED
DETAIL "A"
TO POWER UNIT
FROM POWER UNIT
CHAIN
DETAIL "B"
B ELECTRIC POWER UNIT is geared to move floor segments at 10 feet per minute, has ample power to move 40,000 lb. loads. Motor is powered by auxiliary battery (furnished at same voltage as truck battery) kept charged by truck or tractor generator. If 110 v. outlet is available at all pickup or delivery points, a 110 v. motor can be supplied and battery eliminated (optional feature).
DETAIL "B"
MOTO-VATOR KIT PARTS SHOWN IN BLACK.
D FLOOR CHANNELS
C MOVABLE FLOOR SEGMENTS are equipped with four rows of roller supports, rollers run in channels (D) attached to van floor as shown. Driving lug engages chain to provide movement of segment. (See detail of standard floor segments, back page).
FLOOR SEGMENT
DRIVING LUG
ROLLER SUPPORT
ROLLER
ROLLER TRACK
TRUCK BED
DETAIL "C"
E REMOTE CONTROL plugs into receptacle as shown. Driver-operator may move about at rear of van to observe loading, moves loads in or out by pressing appropriate pushbutton. Limit switch at forward end of van prevents overtravel.

IX. A-1 *Watson Moto-Vator*



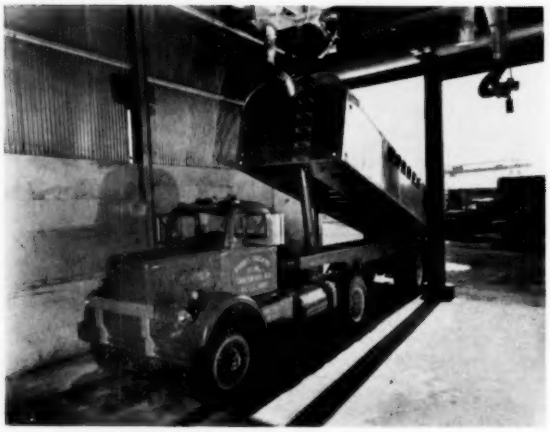
FROM LOADING DOCK

- The THOMPSON LEVELODER adjusts to any loading dock level.
- Swift, safe, hydraulic control raises the entire body to any height up to 52 inches.
- Loaded truck lowers to rest on springs and locks in position for road travel.

TO STREET LEVEL

- The THOMPSON LEVELODER body lowers to pavement so that floor is level with curb.
- Deliveries can be made from either side on one way streets, or from rear.
- Cargo can be unloaded with ease and much faster than by any other method.

IX. B-1 *Thompson Leveloder*



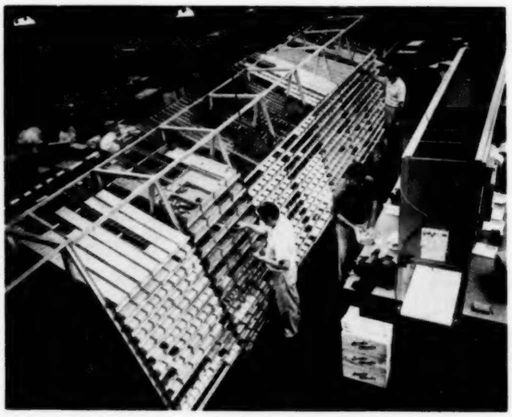
IX. C-1 *Fruehauf Tank Trailer*

GARRETT PRESS
ZELL
PAPER

IX. E-1 *"Truckyback"*

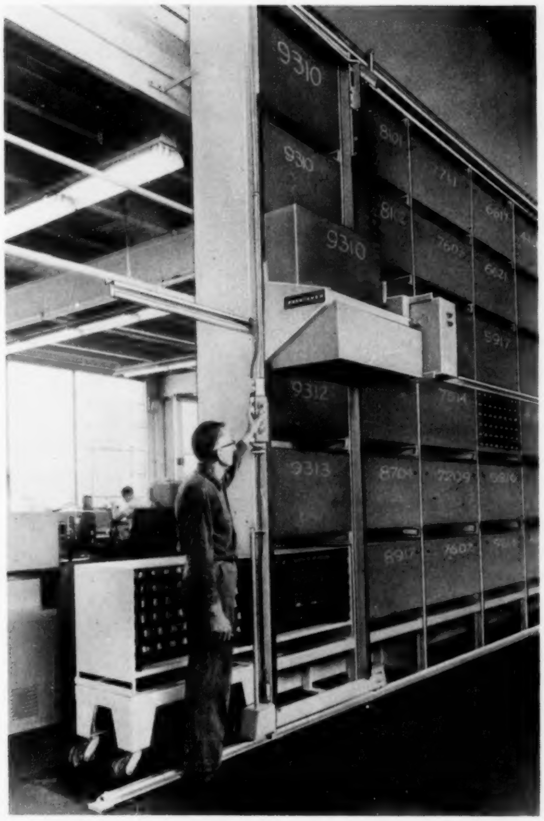
GARRETT PRESS
ZEL
PAP

IX. E-2 *"Truckyback"*

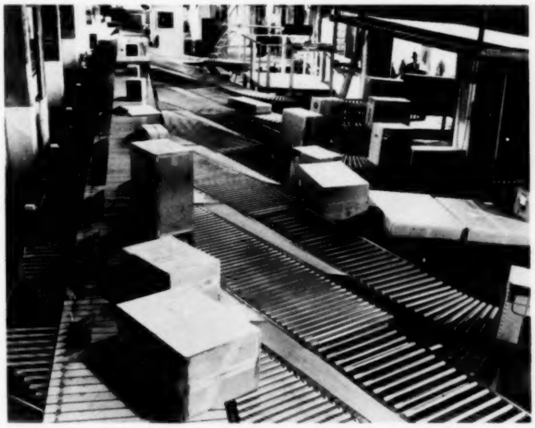


X. A-1 *North American Equipment Quik-Pik Gravity Storage System*

X. B-1 *Material Handling Standard Palletflo Live Storage Rack*



X. D-1 *Triax Equipment Company Skyrak*



X. B-3 *Railway Express Agency — Electo Automated Assorter Conveyor*

XI. F-1 *Douglas Aircraft Co. Glide-Aire Handling System*

X. C-1 *Lamson Corporation Palletizer*

SOME PRINCIPLES OF MANAGEMENT CONTROLS

by **E. H. MacNIECE**
Technical Consultant
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Mr. MacNiece has had broad and diversified experience in management principles and techniques including such areas as production planning, industrial engineering, and supervision of engineering and production for such firms as Durant Motors, Western Electric, du Pont, and I.B.M. He is the author of numerous papers and two books: *Industrial Specifications* (1953), and *Production Forecasting, Planning and Control*, Second Edition 1957.

SOME PRINCIPLES OF MANAGEMENT CONTROLS

by E. H. MacNiece

Technical Consultant, Permacel,
New Brunswick, N. J.

EVER since man began to produce goods and services, the facts and figures that he used in his enterprises have been shouting warnings to him about what was to happen at some future date. Only recently have we learned some of the language of these warnings and signals and to understand what they mean. This understanding has helped us to control better the destinies of our companies. More importantly, it has given us an insight into some of the principles that must be applied to our activities if we really want to control effectively the functions of industry and commerce.

It will be pleasant to explore with you some of the steps that are required before control can be achieved. It will be interesting to present arguments to show that elements of control are the same, whether they are applied to Production Control, Cost Control, Quality Control, Budgetary Control or even the control of automated processes. An attempt will be made to differentiate between control and review.

May I preface this exploration by repeating a colloquy in a Sunday School class? The teacher asked Johnny what he must do to be forgiven. Johnny thought for a moment and replied that he would first have to sin.

We can learn an important lesson from Johnny. Many otherwise well-informed people think that control starts before something is done. Our predictive skills have, of course, been greatly improved. Many provisional controls such as estimated budgets or M.T.M. can precede operations but real control, which is actually an adjusting process, must follow operation just as surely as forgiveness follows sin.

OPERATION

The first step in the control cycle after careful manufacturing and planning is operation. In it, the act of doing something, some faults will be obvious and therefore easily corrected. Other faults will be more concealed requiring the steps that follow to reveal them so that they can be dealt with.

MEASUREMENT

Think of almost any factor in business and commerce and our Industrial Engineers will find some way to measure it and describe it in numbers. The second step is to measure what is being done. If the function is Quality Control the variations in physical, chemical, electrical, dimensional and other properties are measured. In Production Control, all operations are measured to determine the time required for their performance. Also, the capacities of equipment must be measured. In Budgetary Control, measurement will produce ratios of expenses to direct operation costs. In Cost Control all factors measured in terms of quality, waste, operating effectiveness and expenses will tell what costs are, as operations are currently performed. In automation, electronic and mechanical operations must be measured accurately in terms of milliseconds before the whole system can be integrated.

CAPABILITY STUDIES

Analysis of measurements in step two aided by many reliable statistical techniques can project accurately what can actually be done. Managers try frequently to achieve the impossible in a given system and just as frequently they could produce many times as effectively in other systems if they first knew the true capabilities of their production systems.

Take Quality Control for example. Measurements and statistical techniques can tell quickly whether or not a process can produce within required limits. If it cannot and the tolerances are realistic, steps can be taken to contrive processes or equipment that will. As Dr. Joseph Juran[2] says, "The product tells on the process".

If one or two machines among several of the same kind have the capabilities for producing within required limits and the remainder produce outside-limit material it becomes obvious that the remainder need repair or modification.

When the percentage of defects generated by some workmen is inordinately lower than those of other workmen on the same work, it becomes clear that there may have been some improper selection and placement or that job training is required.

It is almost frightening when we learn how little some managers really know about their production and quality capabilities and continue in blissful ignorance to produce ineffectively. It is even more frightening when we contemplate the probable number of similar situations about which neither we nor anyone ever learns.

An European businessman asked me to come to his factory and consult with him on Quality Control. When I arrived he told me that he used the most modern American methods. He had read about Statistical Quality Control. He would like to add this new tool to his collection of techniques for modern management. How should he begin?

I explained that to start we should measure what was presently being done. If his control of quality was satisfactory as shown by this audit he should continue his present control arrangement. If it was not, then we could discuss some statistical approaches to the problems.

We needed specifications. Did he have specifications? He had blue prints for his machined parts and performance requirements for his finished mechanisms. These were specifications; so he selected several, and we went to the machining department.

We checked dimensions for two hours without finding one conforming measurement. My friend was extremely embarrassed. He wanted to give me an honorarium and have me return to Paris. He begged me not to tell his competitors about this sad experience.

This was no place to stop. We must ask the next question. What were the process capabilities? Perhaps the machines were incapable of producing within the tolerances. No, this could not be. He had started the enterprise alone and he had set the tolerances and he had moreover maintained dimensions within them.

Perhaps the tolerances were too close. Suppose we were to observe the assembly operation. This proved to be the typical old work arrangement. On each side of the room were thirty assembly benches complete with small bench lathes, files, vises, bending bars and surface plates. Each man performed all operations on a machine.

As we passed one work place, one man had just finished the assembly of a complete machine. When I asked how long it had taken to assemble the machine, he replied that it had taken about seven hours. He and the owner were shocked when I asked if he would disassemble the machine but since I seemed to have some reason for such a request he stripped the machine and placed all the parts on his bench.

Then I asked if the machine could be reassembled. Twenty-eight minutes later it was reassembled and running. The owner suddenly realized that the difference in assembly time of about six and one-half hours was more than the total machining time per machine. His face showed rage and it was only with fast talk that he was induced to return to his office where he blew his stack.

The next day a complete set of oversized parts for a machine were collected. These were remachined to fall within blueprint tolerances. When they were given to an assembler he put them together in a little less than an hour.

The owner of the business had learned a good lesson in process capabilities, but I was about to learn a lesson in Fayol's function of management known in Europe as *Command*. My host called a meeting of the assemblers. He told them that their poor work caused more adjusting and re-machining time in assembly than the parts were worth. Starting immediately, all dimensions would conform with blueprint requirements or he would discontinue the the machining operations and purchase the parts from another company.

I visited the owner about a year later. He had eliminated more than half of his assemblers and transferred them to machine operations. His work force had increased ten percent. He had reduced the selling price of his product and his production and sales had tripled.

Any attempt to control quality without first knowing process capabilities can produce only confusion and disappointment.

Industrial Engineers have developed the science of Work Measurement to a degree that production capabilities can be accurately defined. Many managers still try, nevertheless, to control production with only a vague notion of the output capabilities of their work forces and facilities.

As World War II impended one company decided to build and equip a factory exclusively for war production. An Industrial Engineer was assigned a project for layout, design and equipment of this proposed war plant. Another Industrial Engineer shocked his principals by stating that in his opinion the then existing production facility was capable of producing civilian production, and war production with some capacity to spare.

His principals were wise men and as such responded to this heretical outburst by simply saying, "Prove it".

This engineer did not back down nor theorize. He asked for authority and staff to measure every operation that was performed. When he had his measurements assembled he presented them, with summaries showing that the then present facility was capable of producing 80 per cent more than it ever had produced and with a few process modifications involving a reasonably small capital investment, 140 per cent more output than had ever been achieved could be attained.

The final proof came when the stimulation of hostilities took effect and his measurements started to prove correct for one operation after another.

No. The war production facility was not constructed nor equipped but some of the equipment arrangements for it was used in the old factory.

In Budgetary Control some general ratios for supervisory, staff and other expenses can be set on a pro forma basis but best results are obtained when proved capabilities are demonstrated by operation and agreed to by those who are accountable for operating performance.

Cost Control uses the measurements of Time Study, material utilization and expense ratios to compute objective costs. Actual costs are used for current financial planning but progressive Cost Engineers set objective costs based upon measurement.

In automation, process capabilities must be measured accurately. Fortunately in automated processes, disturbances can be introduced to simulate their performance under adverse conditions and thus prove predictively their true process capabilities.

FEED-BACK

If you shoot a rifle shot at a target and cannot see or know where and how close to the bull's-eye the projectile hit, your next shot will likely be just as wild or even wilder than the first. If you do know where the first shot hit, you can adjust for the next shot and thus improve your marksmanship. In this exercise it is important that you know the result of one shot before you fire the next. If you receive the result information one month later it will be of little help to you.

Information received after the performance of an action in time to be used as the basis for future performance is known as feed-back. Feed-back is a vital element of control. The other elements of control are action, evaluation, and adjustment. If we visualize a circle and equidistantly upon its circumference we place the notations Action, Evaluation, Feed-back and Adjustment and think of this sequence rotating in continuum we have a closed circuit system of control.

In Quality Control the closed circuit takes the form of a circular rotating sequence upon which are the notations Produce, Test, Feed-back and Adjust. Most progressive companies know that they cannot afford to make large quantities of products in open circuits and then sort the good ones from those that are unsatisfactory.

This feed-back information should be used to reduce controllable variations in dimensions as well as the more complex physical, chemical and electrical properties. Continued measurement of dimensions by attributes inspection only lets us know which parts pass and which fail. This feed-back information is of little value in permitting us to know what the variations are and it comes too late for any dynamic corrective action.

Attributes inspection can sometimes be humorous or sad depending upon one's point of view. When visiting European factories, I was always interested in organizational patterns. In one factory, I observed a workman gauging dimensions of machined parts. I asked him if he were the Chief Inspector. He smiled and pointed to another less active man who was the Chief Inspector.

What differentiated him from the Chief Inspector? The workman replied that the Chief had the extreme maximum limit gauges.

This was puzzling to me so I talked with the Chief Inspector. Yes, there were three sets of gauges. One close-limit set was used by the machine operators. The inspectors used a set that had more open limits, and the Chief had the extreme maximum limit gauges.

Operators gauged each part as it was made. Any that were non-conforming were set aside. The Inspectors gauged these. Any, the dimensions of which did not fall within the limits of their gauges, were referred to the Chief Inspector who used his wide open-limit gauges on them.

When I asked about the variability of dimensions, the Chief Inspector told me that micrometer measurements could give this information, but it was not needed since dimensions seldom were outside the maximum limits.

A subsequent visit to the assembly department revealed some sad feed-back information, the language of which was not being understood. With files, grinding wheels, bench lathes and polishers, the assemblers were proving how much these three sets of fatuous gauges were actually costing.

In Production Control the system is somewhat more complex. This is so because two factors compound the difficulties of adjustment. Even with best forecasting and planning, sales will not always conform with forecasts and production outputs will not always be exactly the same as those that were planned.

I like to think of this complex situation by visualizing a man on a trapeze swinging over a large metronome both of which continually change their speeds. Confused expressions on the faces of students have caused me to reserve this analogy for my private amusement. The diagram in Figure 1 illustrates better the cycles in the control of production.

In it, imagine two rotating sequences of the basic elements of *Action, Feed-back* and *Evaluation* that converge in a compound *Adjustment*. This is Production Control based upon live, current information. There is another arrangement of functions that also operates to achieve control. Imagine an additional adjustment performed in a servo-mechanism type of control in which the function of Expediting stock shortages exerts a force in one direction and Inventory Control of excess stock exerts a force in the opposite direction and thus achieves equilibrium or control. Most progressive companies depend upon these two intermeshing closed circuit systems as well as the servo-mechanism type of adjusting functions to control their production and stocks.

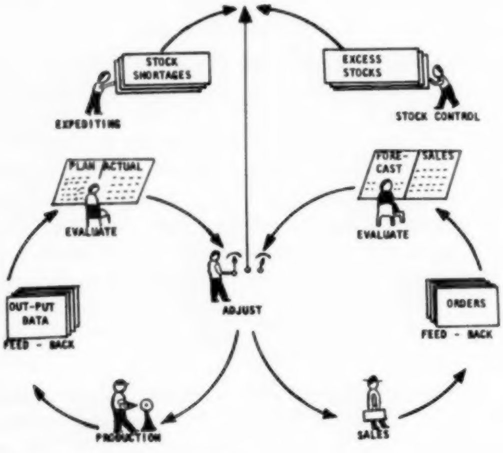

Figure 1

A Diagramatic Representation of Production Control

The illustrations are intentionally simple to project principles. What actually happens is often much more complex, involving magnetic drums and other electronic equipment, but the principles are the same. The diagram may present a notion of rather gentle action but the impacts upon and dislocations of production by rather small fluctuations in consumer sales are rather startling. If you are interested and want to be startled and even shocked, I suggest that you study the research on this subject conducted by Professor J. W. Forrester[1].

In Budgetary Control and Cost Control the principles of control are on the same basis of Action, Evaluation, Feed-back and Adjustment in closed loop circuits.

In automation, the results of closed loop control with feed-back are easily understood because the time intervals between action and adjustment are so rapid, but this rapidity makes it difficult to see what is actually happening. The study of a simple automated circuit will give the student a much broader insight into the whole subject of controls.

REVIEW

Control as we have discussed it concerns dynamic Operating Management. Professor Alex W. Rathe[2] has dignified Administrative Management by avoiding the semantic coarseness of the words control and regulate. It amuses me to observe how a word used in one sense produces a nasty meaning and in another is perfectly acceptable. An executive will, for example, spend an hour at his luncheon club telling of the evils of dictators and then he will return to his office, dictate letters to his secretary and thus by all the laws of language become a dictator.

As engineers it will be difficult for us to abandon the word *control* because it is a good engineering word and we like it and understand what it means. If we are to feel at home in the top echelons of management, perhaps we had better become acquainted and friendly with the word *review*.

Review seems well chosen as it differentiates between the somewhat slower but more all inclusive considerations of the enterprise as a whole and the more rapid evaluation that must precede an equally rapid adjustment in the operating scene.

I have long sought an analogy that would show the difference between the evaluation in operating control and review with its implied adjustments in administration. I have two large greenhouses that are rented to a tenant. I am responsible for contriving and maintaining a heating facility that will maintain temperatures in the greenhouses between 60°F and 90°F. During daylight hours the solar heat would increase the temperature to 130°F if it were not for thermostatically operated ventilators that open when the temperature reaches 75°F. Another thermostat starts and stops the oil burner. An aquastat stops the oil burner when the water temperature reaches 180°F and starts it when it falls to 160°F. These were my operating staff when we started operations. Each had dynamic control functions to perform and each had been instructed what to do under certain circumstances.

My tenant installed a Bristol recording thermometer that made autographic records of what happened during each week. This was the reviewing function. It did not hasten to make adjustments. It did, however, show what adjustments should be made in the total situation. During the early fall months it showed that the burner thermostat was operating between 60°F and 68°F by a saw tooth configuration of the record chart. This was adjusted to operate between 60°F and 62°F with a significant fuel saving.

As the colder season approached the temperature fell below 60°F at night when the outside temperature approached 0°F. The chart showed that this happened at about 11:00 P.M. By simply checking all the controls at that time it was found that the boiler water temperature reached 180°F and the aquastat stopped the burner when the thermostat was calling for heat. The aquastat cut off temperature was increased and the state of control was improved.

As real cold weather came on the inside temperature dropped below 60°F at about 9:00 P.M., and it was not until 11:00 P.M. that it reached 60°F. A visit at 8:00 P.M. showed that the daytime solar heat caused the burner thermostat to be inoperative and the boiler water temperature, therefore, dropped to below 100°F. A surface aquastat on one of the hot water header pipes was connected with a program device that called for a water temperature of 150°F at 4:30 P.M. and cut off at 6:00 P.M. This corrected the whole system so that its operation has been satisfactory. The review continues so that any non-conformance can be quickly detected and intelligent action taken.

I hope that you like this analogy. It is our language, the language of engineering, and it is a simple one.

The effectiveness of dynamic control and administrative review is primarily from keeping us from searching for trouble where none exists. One caution about controls and review. Adjustments should not be set for too close control. In mechanisms, too close control will create *hunting* and this results in machines wearing themselves out by too frequent adjustments and their controlling devices becoming fatigued and confused. And so it is with Engineers and Managers. If their adjustments are too frequent they wear out, become tired and confused and fade away.

CONCLUSION

It would be helpful if we could summarize the foregoing in crisp clear-cut terms like those in Newton's Laws. Since we have not learned all the language of feed-back we must be less concise and express what we know in a homelier yet simple way.

1. We perform some act.
2. We measure the factors associated with the act.
3. From these measurements we determine what can be done.
4. Then we figure out what we would like to or should do.
5. Information about our current actions are fed back for evaluation and review.
6. This information is evaluated by comparing performance with capability.
7. Based upon the evaluation, adjustments are made.

The dynamic cycle of *Action, Feed-back, Evaluation,* and *Adjustment* can be applied to almost all of our activities to achieve and maintain control. Control is the day-to-day function of Operating Management and, when properly applied, eases its burdens by keeping it from looking for trouble where none exists.

Review is the broader Administrative Management evaluation of *all* factors in the operation of an enterprise. Since there are complex interactions between these many factors, review will indicate corrective action deliberately and more slowly than operating control.

I hope that you will excuse me for using examples in the European scene. This was done intentionally to make you feel superior. Now to make you mad and motivate you to look for them, there are just as many ineffective industrial practices in our own country.

Will you accept some of the things discussed in this session as Management Principles? If you will not, please accept them as good generalizations and use them. Will you also share with me the gratifying realization that as Engineers and members of the American Institute of Industrial Engineers our contributions in American industry will bring advancing human welfare. Nothing can cause us to fail.

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section 25

AUTOMATION AND MATERIALS HANDLING

A PROBLEM IN SYSTEM COORDINATION

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AUTOMATION AND MATERIALS HANDLING
A PROBLEM IN SYSTEM COORDINATION

by Edward H. Abbe

Application Engineer, General Electric Company

INDUSTRIAL automation has become the modern cliche for the solution of all the various problems of manufacturing. However, automation isn't a synonym for mechanization. In the materials handling area, mechanization has been progressing since the invention of the wheel and the lever. Automation begins when such functions are automatically programmed or directed. Thus automation may be termed a system which not only includes mechanized functions, but also directs and programs them. Just because we motorize a wheelbarrow doesn't mean we have automation.

Another broadly used term is "materials handling". In the general sense it includes everything from the mechanical gadgets such as tote boxes, carts, platforms up through elaborate conveyors, elevators, bulk handling devices, or anything you can think of that is used to aid in the movement of all types of goods. For our immediate purposes we can narrow this down to cover only those directly associated with a manufacturing enterprise and, in particular, those required to move goods, both finished and in process, through a particular manufacturing cycle, within the four walls of a plant.

It may be said that there are two main categories of materials handling problems within the plant, and these are:

1. Storage
2. Distribution

The storage of the materials used in the manufacture of products includes stock-rooms, warehouses, accumulating areas and any other storage area needed to support the actual manufacture and the final delivery of the particular products involved. Distribution covers the means of moving the various parts and materials between the various storage areas to the processing machines and the ultimate shipping means. Thus storage denotes a static condition and distribution means movement and in both cases no value is added to the products. However, *cost* is added and thus these two areas of the manufacturing cycle are a prime target for cost reductions. Money saved here reflects directly onto the profit ledger.

The interesting fact is that the various parts of the storage-distribution system in a typical plant are closely related. Just because savings can be made in a specific part of the cycle it does not follow, necessarily, that the maximum savings can be made. For instance, in the case of a child's wagon it may be cheaper to stock the parts of the wagon rather than a complete wagon, or to stock the parts unpainted, or to place the finished article into storage knocked-down rather than assembled. Less floor space may be required and a better balanced production rate may be achieved. A recent investigation in the papermaking industry revealed that considerable savings could be obtained by stocking parent rolls of paper and processing them as needed rather than storing the final product which sometimes required repacking of finished goods in order to deliver the desired products to the customer.

The conclusion to be reached is that a *systems approach* must be used. Only after the cause and effect relationships of each step in the process are understood is it possible to determine the optimum plan. The degree of automation economically feasible can then be determined and the final plans for automation can be completed.

THE TOOLS OF AUTOMATION

Having determined some of the definitions and problems involved in a general sense, a look at some of the automation tools available is important. Some of the tools will be helpful even before the overall system is completed. In fact one of the vital business tools of today, the computer, will be most useful in analyzing the data needed to arrive at the optimum system for the particular manufacturing process being studied. Such items as production rates, sales demand, material flow, brand changes must be carefully and completely analyzed and with today's volume of business it is almost impossible to do this effectively with manual methods. The computer itself, when properly selected for the particular job, will become a necessary part of any efficient automation system. In a feed-back type control system the computer can be used to continuously monitor the process and in turn provide the necessary information for correcting the operation of the automated system.

Many new electrical tools have become available in the last few years and have opened new frontiers for the reliability and feasibility of automatic control systems. Some of these are:

1. Static switching control
2. Product recognition devices
3. Program control
4. Memory systems

Static switching control has introduced a whole new concept in the reliability of complex control systems. A static element (or logic element) basically is a device to replace the conventional relay and accomplishes the switching function without any moving parts. The elimination of contact making relays in a complicated control obviously will do much to reduce maintenance and to decrease down time due to relay failure. Static units are available today in a large variety of types, some making use of the magnetic amplifier principle and others using transistors, diodes, and other recently developed electronic concepts. In general, these new devices will accomplish the same functions as a relay in less space and often in a more straight-forward manner. Careful and thoughtful application of this type of device is essential since at times it will be logical to use conventional relays where frequency of operation and atmospheric conditions are moderate.

Many recent developments have pointed the way to eliminating one of the bottlenecks in any automation system where recognition of the product is required in order to control the process. Although very few standard devices for this purpose are presently available, nevertheless, the know-how is here now for making devices that will do a specific job. In fact, since almost every problem in recognition is different, it is impossible to say that any one type of identifier is suitable for all applications. For sensing the presence of products which may be identified by a code marking, such as goods packed in cardboard containers, a photoelectric device is now available which will identify thousands of different items at speeds up to at least 200 feet per minute. Other techniques which might be used for this purpose include magnetic inks used for marking, photoelectric sensing of size and shape, shift register systems which will remember where each item is, and mechanical followers such as tape, and pin-wheels. In fact so many new techniques are coming into the picture that only an expert can keep up with the developments and make intelligent applications of them. All of these devices except the mechanical followers (which must be synchronized with the movement of the product) are capable of identifying products regardless of the mix and flow rate; in other words they will follow a random mixture of product flow.

In the area of program control many different types are available. These include magnetic tapes, drums, punched cards and tapes, all of which permit quick changing of the program when conditions or processes change. Fixed programs can be achieved by complex matrices or by sequencing control composed either of static elements or of relays. Thus an ordered sequence of events in any process can be readily programmed by applying any of these currently available techniques.

Where memory is required, such as remembering where each product has been stored so that it can be readily counted or withdrawn automatically, the same tools that are used for program control may be used.

It is quite obvious that with the plethora of equipment available, it is necessary to apply them with caution and with due respect for the particular system involved. Many companies today are specializing in just such control systems but there are no standard systems that can be applied across-the-board to any and all processes.

A SYSTEMS APPROACH TO MATERIALS HANDLING AUTOMATION

A logical approach to the systemized automation of any or all of a particular manufacturing process is important. The first step of the plan may merely call for a more useful mechanical layout with a simple dispatching function. If the proper mechanical equipment is installed in this first step it will be less costly and much easier to take the next steps. This is one more reason for a thorough understanding of the operation and potentialities of the process. Since the shipping warehouse of the average factory is often a bottleneck, and one that is difficult to solve, a step-by-step description of such a warehouse is described in the following paragraphs.

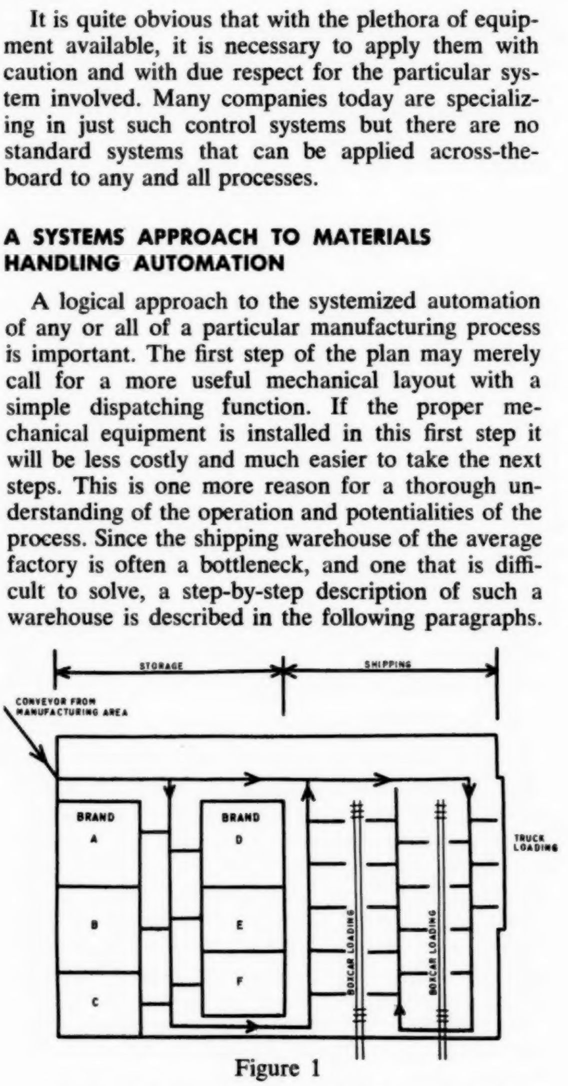
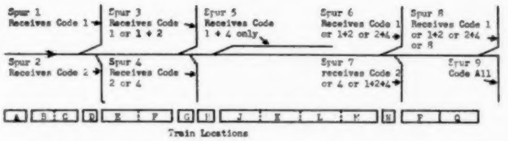


Figure 1

Manual System for a Simple Conveyorized Warehouse

A typical manual warehouse is shown in Figure 1. All loading, unloading and direction is accomplished manually. Goods flow from the production area on a conveyor into any one of six storage areas. At the proper storage area they are removed from the conveyor and placed in bins, stacks, or on pallets by manually operated carts, fork-trucks, overhead cranes, etc. When needed for shipment later, they are removed from storage by the same means and transported to the shipping area.

The necessary production, shipping, and inventory records are maintained manually by a large clerical force. Additional labor is expended in preparing order-picking lists, and in checking inventory to see that the necessary goods are on hand to fill the orders.



Spur Selected	Binary Code for Four Channel Shift Register				Train Locations	Switch Operated
	8's	4's	2's	1's	A	None
1	0	0	0	1	B–C	1
2	0	0	1	0	D	2
3	0	0	1	1	E–F	3
4	0	1	0	0	G	4
5	0	1	0	1	H	5
6	0	1	1	0	J–K–L–M	6
7	0	1	1	1	N	7
8	1	0	0	0	P–Q	8
9	1	0	0	1	–	–

Figure 2

One line diagram shows operation of the memory and shift register system

One of the next steps in mechanizing a warehouse is to add dispatcher control. In this type of system the dispatcher observes the flow of production into the warehouse and either electrically or mechanically directs each product to the correct storage area. In a typical mechanical system the dispatcher attaches a pin on the tote box in the correct location to trip a director vane at the desired storage area transfer point in the warehouse. A similar electrical system uses a dog and limit switches. Another electrical system, used when production rates are slow or when one product is produced continuously for long periods of time, is a pushbutton scheme in which the dispatcher preselects the transfer point.

A more sophisticated method makes use of a shift-register technique. In this control scheme the dispatcher merely pushes a button for the desired storage area as each case or tote box passes by. The shift register then takes over and electrically follows that particular case and sees that it is discharged at the proper transfer point. Such a system can be applied up to rates of nearly 200 feet per minute and still allow the one dispatcher to keep production rolling. The diagram in Figure 2 shows how a shift register scheme operates at GE's Appliance Park shipping warehouse. In Figure 3 the dispatcher's station and the control panel for this installation is shown. The shift register was made up of static switching elements and has proven to be reliable and accurate in operation.

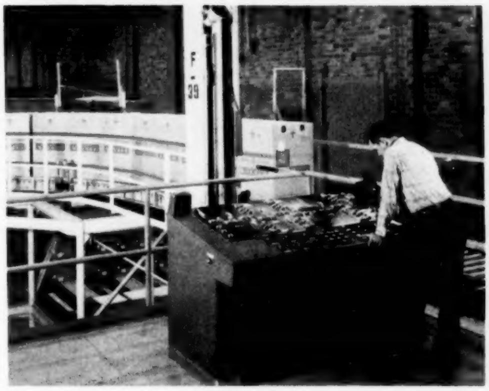


Figure 3a

Dispatching System

On an operator's console, dispatcher selects proper storage area for a conveyor train as it enters the warehouse at GE's Appliance Park plant. Then . . .

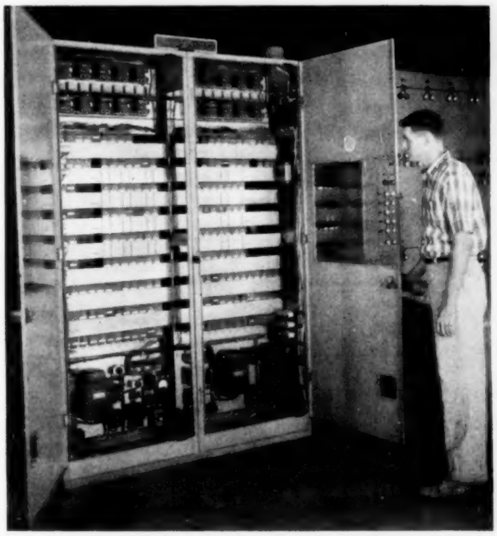


Figure 3b

Dispatching System

static controlled shift register keeps track of the train as it moves through the warehouse. Graphic lines and indicating lights help maintenance personnel follow operations.

A third step would be the use of sensing devices. These devices would be capable of identifying the product photoelectrically or magnetically, or mechanically by code, weight, size, or material. By means of a preset program set up by punched cards or pushbuttons the sensing devices would call for the transfer of each product at the correct storage area. See Figure 4.

The next step towards the ultimate system would be the addition of automatic loading and unloading equipment in the storage area. Automatic transfer devices coupled with conveyors, elevators and other positioning means would take the material from the production conveyor and deposit it into storage racks. Similar means, or the same equipment, would be used to do the order picking and the delivery to the shipping area. Such a system would be programmed by the dispatcher. At this point the clerical work would still be done manually.

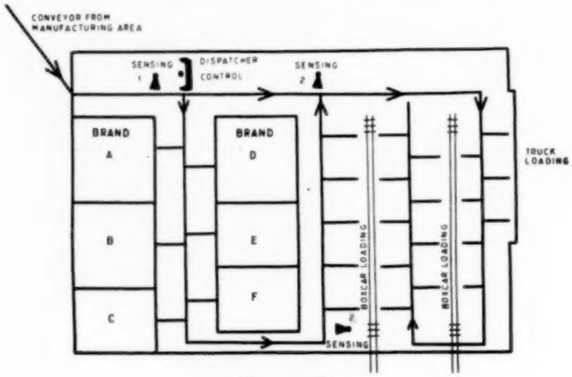


Figure 4

Warehouse Using Sensing Equipment

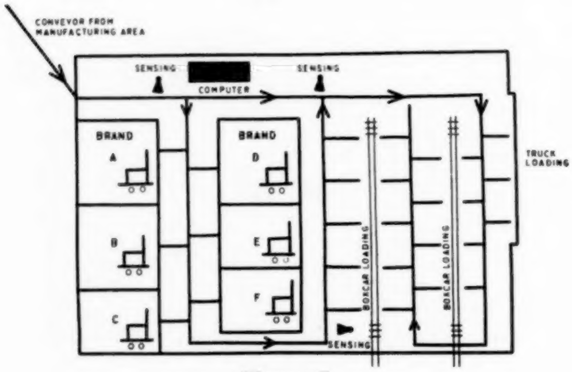


Figure 5

A computer controls the material flow in the warehouse, using the sensing system, automatic loading and unloading, and data logging

The final step in the automation of the warehouse would be the addition of data logging equipment, as shown in Figure 5. Such a system makes use of the previously installed equipment plus a computer. The loading of the storage area would proceed under the control of the data logging system which would analyze the production rate and determine the correct storage of the produced goods. It would also receive incoming orders and send them to the shipping conveyances in the proper sequence. The system would also prepare customer billing and would inform management of the proper production rates to be maintained in the face of incoming orders.

DESIGN FOR INDUSTRIAL ELECTRICAL CONTROL SYSTEMS

In specifying and designing the control for material handling automation equipment some of the following points should be considered:

1. Reliability
2. Ease of maintenance
3. Environment conditions
   (dust, corrosive gases, heat, humidity, oil fumes, etc.)
4. Flexibility
5. Complexity

A very important item, in this day of rapid change, is flexibility. Systems must be designed with full cognizance of the changing pattern of tomorrow's production. Such things as change in products, increase in production rates, and improved methods may cause changes in the materials handling system. Properly planned control which fully recognizes these future changes can materially contribute to reduction of revamp costs. The modular approach, using equipment specifically designed to meet the exacting requirements of industry, provides such a control.

Reliability and ease of maintenance are necessary features in reducing down time. A properly designed control system should aim for a goal of maximum availability. It is particularly important to incorporate such details as plug-in devices, expendable units, wiring troughs, static switching and other static components to minimize component failures and permit quick and ready replacement when required. The designers of such equipment must have a thorough knowledge of the requirements and conditions for each individual application in order to provide the most economical and yet reliable system.

THE ECONOMICS OF AUTOMATION

In justifying any of the systems which may be designed for handling materials in a plant, economic factors and the effect of company policies must be carefully weighed. The most obvious and easily measured source of cost improvement is the reduction of manual labor. However, this alone will not pay for the automation of a system, especially if the existing manual methods have been mechanized for most economical operation. In this area the very tools selected to reduce manual labor are important, for if the tools cannot be readily adapted to an automatic system the cost of scrapping them may easily wipe out money set aside for the next step. This is another reason why the step-by-step system approach to in-plant materials handling is so important.

Other sources must also be tapped to pay the bill for automation. Some of these are:

1. Improved inventory control
2. Reduced distribution costs
3. Reduced time to locate and use the material
4. Reduced storage space
5. Improved utilization of clerical forces

Some of the reasons for automation are more intangible and cannot be readily measured in dollars. For instance, the improvement in the entire manufacturing cycle due to the efficient handling of the goods-in-process, the elimination of confusion, and the accurate reporting of production facts all contribute to the justification of automation in the growing complexity of modern manufacturing. It might be said that the tremendous output of goods in the average factory today, despite all efforts of standardization, is becoming too complex for the human mind to comprehend without the aid of industrial automation.

INC.

THE EFFECT OF DEFERABLE WORK ON WAITING LINE PROBLEMS

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As an Industrial Engineer at the Kodak Park Works of Eastman Kodak Company, his assignments in the work measurement field have consisted of methods and systems analyses, production planing, quality control, and waiting lines.

Mr. Peacor has presented papers at Quality Control Conferences and Industrial Management Council Conferences. He is also co-author of *The Evaluation of Color Print Quality* published in the AIIE Journal.

THE EFFECT OF DEFERABLE WORK ON WAITING LINE PROBLEMS

by Robert W. Peacor*

Industrial Engineer, Eastman Kodak Company

THE prediction of interference for a service type operation requires the consideration of both deferable and demand work. The significance of each type will vary depending upon the conditions. But, it should be recognized that the effect of deferable work *does exist* and for some operations can be the most important factor of the investigation. For example, it is not uncommon for *all* of the work performed in handling operations to be deferable. In order to predict the number of handlers for these operations under specified conditions queuing models, which assume that the work occurs on a demand basis, may not be sufficient.

Consider, for instance, the analysis that might be made to predict the increase in productivity for a punch press operation when the operator is asked to run two machines instead of one machine. A practical approach to the problem would be to measure the existing operation and to use the results in a suitable queuing model. Let's examine how this might be done. Assume for the one machine operation that the measurement results show that the proportion of total time for run time = .90, repair time = .10 (demand work during down time), and deferable work time = .25 (run time work usually done in advance of the need).

For the proposed method, the productivity can be predicted, given the amount of interference. This is conveniently and descriptively shown when interference is graphically plotted versus a total work load index. For now, consider the total work load index as equal to the demand work load index *plus* the deferable work load index. The total index, then, is .35 (.10 + .25) for the one machine operation. Assuming that the effect of demand work is given by the finite queuing model[4,5] and that the minimum effect of deferable work is zero until the operator has a work load index of 1.00, the following graph can be drawn (Fig. 1).

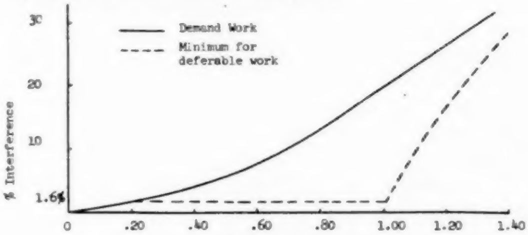

Figure 1

Interference Values for 2 Machines per 1 Operator

This graph sheds a great deal of light on waiting line problems because it defines the *range* of possible interference values for a given total work load index. The total work load index in our example for two machines is *twice* that for one machine or .70 (2 x .35). At this index, the *minimum* possible interference value is 1.6%. This assumes deferable work causes no interference and that the interference caused (1.6%) is due to the two machine *demand* work for an index of 2 x .1 = .2. A reasonable maximum interference value is 10.8%, which assumes deferable work is the same as demand work. Since the true interference value must lie within the range of 1.6% to 10.8% the mid point, 6.2%, can be chosen as the predicted value. This means that the error will be equal to or less than one-half the range, or 4.6%. This may seem like a significant amount of error. But is it? When the error has little effect upon the decision, the answer is no. This could be the answer for this punch press operation. On the other hand, this writer has encountered several problems where an error of 4.6%, or even less, could cause a wrong decision to be made with its resulting consequences. For these problems, a more precise estimate of the effect of deferable work was needed.

An investigation of the available queuing models which apply to deferable work conditions[2,8] has indicated that they do not provide adequately for some of the variables. For this reason, it became necessary to develop a more general model. Consideration was given to the relative costs of a system simulation model compared to a mathematical model. Because the cost of developing a simulation model and of putting the results obtained from it in a usable form (i. e., tables, graphs) was considerable less than the cost associated with a mathematical model, it was decided to develop the simulation model using an IBM 705.

The intent of this paper is:

1. To show the results obtained from this model for each deferable work element.
2. To explain how these results can be used according to the *relative importance* of each variable.

***The writer would like to express his appreciation for the counsel given by Mr. John M. Allderige, Technical Advisor, Industrial Engineering Division, Kodak Park Works, and to Miss Shirley Hall of the Scientific Computing Department, Kodak Park Works, who wrote the program for the system simulation model.**

DEFINITIONS

It is first necessary to define clearly the difference between the two types of service work, demand and deferable, and to explain when each type of work can cause interference.

DEMAND WORK

The majority of the research and development work for waiting line problems applies to demand work conditions.[3,4,5] Therefore, a definition of demand work should agree with this queuing material. This has been accomplished by having the definition apply to service times which are constant or whose distributions may be any shape, and apply to service calls which arrive in any way (randomly, at a fixed occurrence, etc.).

Definition: Demand work is work that the service operator *cannot* start to do in advance of the time when the work needs to be started.

The need for service work occurs when the unit which is serviced stops producing or functioning. At this time the service operator should provide the service so that there will be no interference. If the number of service calls at any time is greater than the number of service operators, interference will occur.

DEFERABLE WORK

Definition: Deferable work is work that the service operator *can* start to do in advance of the time when the work needs to be started.

This definition points out the advantage of deferable work compared to demand work. Therefore, it is reasonable to expect the interference caused by demand work to be greater than that caused by deferable work when there is the same work load for each of the two types of work. (The results will show that this is correct for the majority of the cases.)

There are three characteristics associated with deferable work:

Capacity: The maximum number of occurrences or elements into which each deferable work job can be divided.

Lead Time: The maximum amount of advance time the service operator has in which to start the deferable work element prior to the time when it must be started.

Decision of the Service Operator:
The service operator can decide to do the deferable during lead time. In this way the operation will function more effectively as the work will be started during the productive time rather than during the non-productive time.

An important aspect of deferable work is the variety of ways in which interference can occur. For instance, interference can occur when the number of service operators is equal to the number of units serviced, as well as the more familiar case when the number is less than the number of units serviced. For instance, it is possible to have interference when one operator runs one machine. This is illustrated in the following example:

One operator runs one machine which requires demand and deferable work. The demand work consists of eliminating jams which cause down time. The deferable work consists of supplying parts to a parts fixture. The parts are loaded by hand into the parts fixture and the capacity is 10 handfuls. It takes .20 minute to add a handful and each one contains the amount of parts to keep the machine running for 1.5 minutes. The average run-time between demand work calls is 5.00 minutes. Figure 2 shows one of the more important ways that the deferable work can cause interference at this operation.

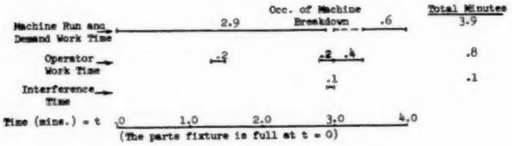

Figure 2

After 1.3 run-time minutes, the operator can start to add a handful of parts. At t = 1.5 minutes, he finishes putting in the parts and then remains idle until t = 2.8 minutes. Since demand work is still not required to be done and he has no indication when it will occur, he starts to put in another handful. At t = 2.9 minutes, the machine jams and the operator should take care of it. However, he cannot take care of the jam until the parts are in the fixture. (He could stop the deferable work by dropping the parts on the floor, but this might be considered ill-advised.) Therefore, the interference continues for .1 minute.

A convenient way of visualizing the way interference can be caused by different types of work on the same machine is by considering the following comparable operation. For the example shown in Figure 2 there would be one machine which would have only demand work (repairs) and one machine which would have only the deferable work job (loading of parts). The problem is then reduced to a one-operator, two-machine problem and can be more easily pictured.

The description of a waiting line problem can be summarized by considering the important components. Figure 3 illustrates these as they occur for an average production cycle according to the definitions.

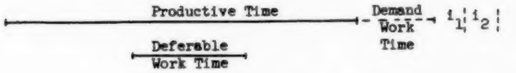

Figure 3

Total Time for an Average Cycle

i_1 and i_2 represent the interference caused by demand work and deferable work respectively. Either or both i_1 and i_2 may be zero or greater than zero depending upon the effect of the type of work. The amount of time a service operator spends on each type of work will also be equal to or greater than zero. The results of the analysis to be described quantify the proportions of the components for any queuing problem so that accurate predictions within the requirements of the problem can be made.

The symbols which will be used are listed here for easy reference.

N = number of units which are serviced, i.e., machines (all units are assumed alike).

s = number of service operators, i.e., machine operators (all operators can do the same work).

h = average service time per occurrence (demand work), i.e., the mean of the distribution of actual repair times (its reciprocal is the servicing rate, $1/h$).

a = average productive time between demand work calls, i.e., the mean of the distribution of actual machine run times (its reciprocal is the arrival rate, $1/a$).

h/a = demand servicing factor, a convenient ratio of the average demand time to the average productive time.

c = capacity—fixed according to the design of the workplace and includes the deferable work element which is presently keeping the unit productive.

$\overline{p}$ = average amount of productive time that can occur *after* an element of deferable work has been completed.

$\overline{X}$ = average time for a deferable work element ($\overline{X} < \overline{p}$). An element represents the minimum amount of work the operator can do conveniently at any one time.

$\overline{X}/a$ = deferable servicing factor, a convenient ratio of the average deferable time to the average productive time.

B_c = average time per basic cycle = productive time per cycle + demand work per cycle = $h + a$.

I_t = total work load index

$$= \left[\frac{\text{Number of Units Serviced}}{\text{Number of Service Operators}}\right] \times \left[\frac{\text{Total Work Time / Cycle}}{\text{Time / Basic Cycle}}\right]$$

$$= \frac{N}{s}\left[\frac{h + \overline{X}\,(a/\overline{p})}{h + a}\right]$$

I_d = deferable work load index

$$= \left[\frac{\text{Number of Units Serviced}}{\text{Number of Service Operators}}\right] \times \left[\frac{\text{Deferable Work Time / Cycle}}{\text{Time / Basic Cycle}}\right]$$

$$= \frac{N}{s}\left[\frac{\overline{X}\,(a/\overline{p})}{h + a}\right]$$

I_m = demand work load index

$$= \left[\frac{\text{Number of Units Serviced}}{\text{Number of Service Operators}}\right] \times \left[\frac{\text{Demand Work Time / Cycle}}{\text{Time / Basic Cycle}}\right]$$

$$= \frac{N}{s}\left[\frac{h}{h + a}\right]$$

I_t', I_d', I_m' are the workload indexes considered in terms of the pace at which the service operator will be working which is other than the "normal" or average pace.

w = average interference time per cycle and includes all non-productive time other than demand work time.

P_c = average time per productive cycle.
$= h + a + w$

i = percent interference time

$$= \left[\frac{w}{P_c}\right] \times 100 = \left[\frac{w}{h + a + w}\right] \times 100$$

p = percent productive time

$$= \left[\frac{a}{P_c}\right] \times 100 = \left[\frac{a}{h + a + w}\right] \times 100$$

f = percent operator idle time

$$= 100 - I_t(100 - i)$$

MAJOR VARIABLES

The results shown in this section explain why and how most waiting line problems which have demand and/or deferable work can be solved by considering a relatively few, but major, variables. This notion is not unique to this analysis. For instance, units of measure that are used for incentive standards or for productivity statements are determined this way.[1] The process of selecting the units is one of choosing the fewest number of variables which reduce the variation to some amount. This amount (precision interval) is specified by the engineer on the basis of the type of decision or recommendation that has to be made.

The work load index is the most important variable for explaining the variation within a waiting line problem. This is intuitively appealing since interference occurs only when all of the service operators are working. In addition to the predictive value of the work load index, it is a term used and easily understood by production supervisors.

Use was made of the work load index in the analysis of the punch press operation described earlier. Figure 1 showed that there is a range of interference values for a given index. The limits of the range will now be described in detail as an understanding of them points out why they can be used as a basis for many decisions.

The limits can be best described by examining the lower limit at its extreme position. This occurs when the demand work load index equals zero. Figure 4 shows the range of values for this condition.

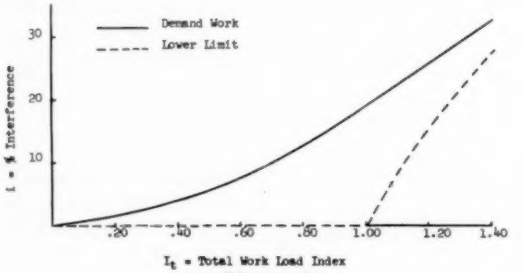

Figure 4

Interference vs. Total Work Load Index

The lower limit occurs when all of the work is defined as deferable work done in its purest sense. This assumes an infinitely large lead time which allows the service operator more than sufficient time in which to do the work and for an infinitely small elemental time which permits the operator to stop instantaneously what he is doing in order to do something else. The interference is 0% up to and including a work load index of 1.00. This is because the work is always done during productive time (run-time). For an index greater than 1.00 the interference is calculated by using the following equation:

$$i = \frac{I_t - 1.00}{I_t} \times 100$$

$$\text{where } I_t > 1.00$$

For instance, this interference would represent the time an operator would have to turn off the machine in order to get caught up.

In connection with an index greater than 1.00, there are three considerations which pertain to any comparison but become more important at the higher indexes. First, it is assumed that the operator will spend the same time doing an element of work as he would with a smaller work load. If it is known that he will work at some higher pace, the interference is calculated as follows:

$$i = \frac{I_t' - 1.00}{I_t'} \times 100$$

$$\text{where } I_t' > 1.00$$

For example, if it is known that an operator will be working at a pace of 105% for It = 1.20,

$$I_t' = 1.143 \left[\frac{1.20}{105/100}\right] \quad \text{and}$$

$$i = 12.5\%$$

Second, it is assumed that the method does not change. Sometimes an operator works more efficiently when his time is limited. When this is known to occur, the realistic time should be used. The third consideration is for the risk that the operator will cut corners. For example, an inspection function is usually not done properly at a work load which does not permit the operator sufficient time. Because of the possibility of producing a product of poor quality, it is usually not economically practical to consider asking the operator to have a work load index of more than 1.00.

The upper limit of Figure 4 shows a reasonable maximum interference that can occur. Only extremely different and improbable conditions can produce more. The values were calculated by using the mathematical model for a finite waiting line (described in the technical notes at the end of the paper) for the condition of two units serviced by one operator. A description of the similarity between the assumptions of the mathematical model and the type of operating conditions that can occur in real life will clarify why these values can be considered as a reasonable maximum for either demand or deferable work conditions. There are four important factors: the distributions of time, the number of service operators, the number of units serviced, and the degree of deferability (this pertains only to deferable work).

Experience has shown that the distribution of service times and the times between service occurrences are very seldom more skewed than the negative exponential distributions (which are used in the queuing model). Even those which tend to be more skewed usually cause only a slight difference in the results. The same argument holds for less skewed distributions. This is especially so for service times since the effect of a constant service time, which is the extreme condition, usually has a minor effect.

The greatest amount of interference occurs for the fewest number of service operators. As the upper limit is based on one service operator, the interference can only be less as the number of operators is increased.

The effect of the number of units serviced upon interference is greatest when the number of units is equal to two, with a minor exception. This exception occurs for three to seven units when the total work load index is greater than 1.00. The greatest difference is only about 1%. Figure 5 shows the differences between interference for one operator servicing 2, 5, 10 and 20 units.

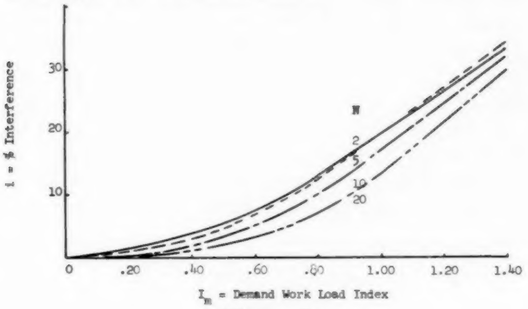

Figure 5

Interference vs. Demand Work Load Index
s = 1 Operator

The fourth factor, deferability, is an interesting one to consider with regard to the upper limit for it emphasizes a primary difference between demand and deferable work. Since the operator does the work many times at his own convenience, the interference effect of deferable work should *usually* be less than that of demand work. Therefore, a conservative prediction (reasonable maximum) of interference will be made for most conditions by considering deferable work as demand work.

On the basis of a description for the upper and lower limit it can be shown that Figure 1 is but a refinement of Figure 4. If part of the total work load is demand work, the minimum line can be changed so as to reduce the range. This means raising the lower limit until it intersects the upper limit at the demand work load index.

It has been shown how one variable, the work load index, can be applied. The only quantitative data which has been used is that obtained from the known queuing model. The remaining discussion utilizes the results obtained from the simulation model (which is briefly described in the technical notes).

The *second* variable of importance is *the number of deferable work elemental occurrences per occurrence of productive time.* The number of elements is equal to $a/\overline{p}$ and has already been used as part of the definition of the lower limit. The average time per deferable work element was defined as infinitely small which means the number of elements must be infinitely large for a given work load. An easy way to visualize these infinitely small elements is to consider each time as some increment of an M.T.M. elemental time.

Figure 6 shows the effect of the number of elements upon interference when considered with the work load index. Three curves are drawn for I_m = .20 and I_d varying from .00 to 1.20.

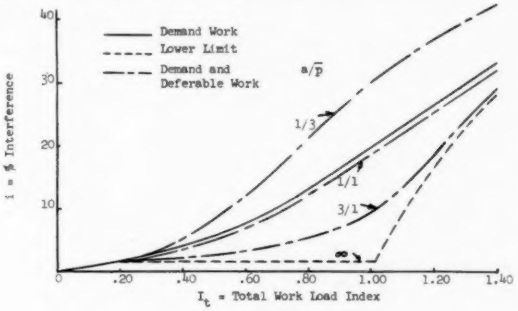

Figure 6

Interference for 3 Levels of Deferable Work
s = 1 operator, N = 2 units, c = *6 elements*

For a given work load index, the interference increases as the number of elements decreases. This is to be expected because the fewer elements take relatively longer to do and cannot be conveniently stopped once they have been started.

The interference which occurs when $a/\overline{p} = 1/3$ is greater than that which occurs if the deferable work had been the same as the demand work of the queuing model. Deferable work is relatively unrealistic when it occurs in this way and is primarily interesting in an academic sense. However, it is well to be aware of the deferable work conditions which can cause more interference than certain demand work conditions.

On the basis of real life operations analyzed, about 85% to 95% of the deferable work conditions fall within the ∞ and 3/1 range, about 5% to 15% within the 3/1 and 1/1 range, and there is a slight chance of a condition where $a/\overline{p} < 1$.

MINOR VARIABLES

Two variables, capacity and lead time, can be generally defined as minor variables. It is conceivable that this could be a misnomer for a few problems, but this was not so for the many operations which have been analyzed. Both variables explained a relatively small amount of the interference.

Capacity takes on a wide range of values in real life. For most operations studied by this writer, capacity is equal to ten through eighteen elements, but may be as low as six elements. For this range of values, from the low of six to the high of eighteen, there is only a small difference in interference. This is shown in Figure 7 for a demand work load index of .20 and a deferable work load index of .80. An extra scale is included at the bottom of the graph for the ratio of the average time per deferable work element $(\overline{X})$ relative to the average time per occurrence of productive time (a). The two scales can be used interchangeably.

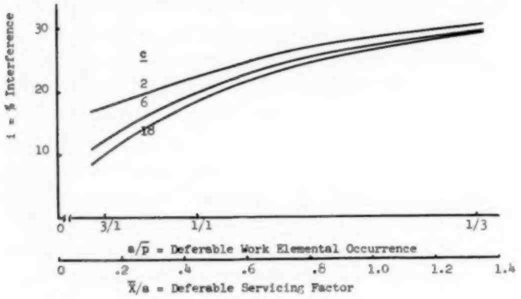

Figure 7

Interference for Various Levels of Capacity
$I_t = 1.00, I_m = .20, I_d = .80$

As is expected, the greatest improvement to a system is made when a very low capacity is increased. The effect of diminishing returns sets in at about c = 6. This information could be helpful when designing a physical layout of an operation or the way a service operator can do his work.

The results shown in Figure 6 considers capacity at its probable minimum (c = 6). Therefore, the effect of capacity for an actual operation will probably be less than that shown. But any improvement will be slight.

Lead time (which is partially a function of capacity) is a variable of minor importance for the same reason as capacity. It is only necessary to be aware that the variable exists and can have a considerable effect for extreme conditions, i.e., when the lead time is less than the average time per deferable work element and the elemental time is variable.

SUMMARY

A waiting line problem consists of variables which affect interference time, productive time, and operator idle time by varying amounts. The variation for interference has been described and a similar explanation could be given for productive time and operator idle time. To say that any one variable is always the only one necessary to use as a predictor is unreasonable. One variable may not reduce the error to a sufficient amount so that an intelligent and accurate recommendation can be made. Neither is it reasonable, in an engineering sense, to use all the variables to analyze all problems. Why spend two or more hours making calculations which require using each variable when the effect of one, or a few, of the variables can be quickly determined by using graphs or tables, giving an answer which is sufficiently accurate to make a correct decision? The method of analysis should correspond to the needs of the decision.

In order to make an analysis, it is necessary, first, to have a good understanding of the variables so that they can be quickly and easily identified, and second, to know or be able to determine the effect of each variable for varying operating conditions. The system simulation technique has been used to quantify the effect of the variables associated with deferable work. These results can be used with the answers of known mathematical models which consider demand work. Generally speaking, demand work and deferable work load indexes used with the ratio a/$\overline{p}$ and a series of graphs like Figure 6 can make a good first pass at all finite waiting line problems and solve most of them very satisfactorily.

TECHNICAL NOTES

QUEUING MODEL

This description is meant to review for the reader the equations and the assumptions of the queuing model used in the discussion of the results. The reader is encouraged to read about the development of the equations[4]. The equations are:

$$\frac{P_n}{P_o} = \frac{N!\,(h/a)^n}{n!\,(N-n)!}$$

where $0 \leq n \leq s$

$$\frac{P_n}{P_o} = \frac{N!\,(h/a)^n}{s!\,s^{n-s}\,(N-n)!}$$

where $n \geq s$

$$P_o = \frac{1}{\sum_{n=0}^{N} P_n / P_o}$$

Where P_n = probability that n of the N units require service. at a given time.

P_o = probability that none (0) of the units require service at a given time.

The assumptions are:

1. The probability density function for the time between arrivals is $(1/a)e^{-t/a}$ (where t is the time between two successive arrivals for a unit.
2. The probability density function for the service time is $(1/h)e^{-t/h}$ (where t is the time to accomplish the service).

From the above equations, estimates of interference, run-time, service time and service operator idle time may be obtained. Because of the common usage of this model, tables and graphs are available which list these estimates and eliminate the need for any calculations.[6,7]

The results of the simulation model are the same as the ones of this mathematical model when an operation is simulated with the same conditions as the ones specified by the mathematical assumptions (a similar comparison can be made for the mathematical model which applies to an arrival rate for an infinite source, i.e., cars arriving at a toll booth, and to other models). This similarity proved very helpful for testing that portion of the logic of the program which applies to demand work for it was known what the results of the simulation should be.

SYSTEM SIMULATION MODEL

Figure 8 is a simplified flow chart of the system simulation model. The major consideration of the model was for the priority levels within and between each of the two types of work. Demand work is always done before deferable work. This is done so as to minimize the non-productive time.

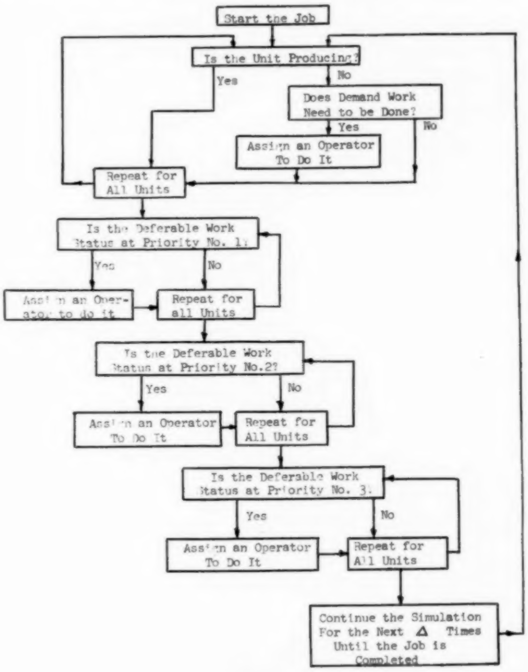
Start the Job
Is the Unit Producing?
Yes
No
Does Demand Work Need to be Done?
Yes
No
Assign an Operator To Do It
Repeat for All Units
Is the Deferable Work Status at Priority No. 1?
Yes
No
Assign an Operator to do it
Repeat for all Units
Is the Deferable Work Status at Priority No.2?
Yes
No
Assign an Operator To Do It
Repeat for All Units
Is the Deferable Work Status at Priority No. 3?
Yes
No
Assign an Operator To Do It
Repeat for All Units
Continue the Simulation For the Next Δ Times Until the Job is Completed

Figure 8

A Simplified Flow Chart

The priority between units serviced within demand work is on the basis of the unit number. Each unit is assigned a number where the numbers go from 1, 2, . . n. This means that if more than one unit requires demand work at the same instant, the unit with the lower number will be serviced first. Therefore, it is possible that the unit that has been waiting the longest may not be serviced first if it does not have the lowest number. This type of priority does not affect the results of the analysis, which is portraying the average machine situation, not individual machine situations.

Within deferable work there are three priority levels. These levels have been determined by observing the way service operators work at a number of operations. Priority #1 occurs when the capacity has been depleted and the unit has stopped producing, priority #2 occurs when the capacity is almost depleted, and priority #3 occurs when there is a sufficient amount of capacity left so that there is no imminent probability that priority #1 or #2 will occur. The priority between units serviced and within a priority level is as follows:

Priority No.	*Basis for the Priority*
1	The unit with the lowest number.
2	The unit with the least amount of capacity remaining.
3	The unit with the least amount of capacity remaining.

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JOB DESIGN RESEARCH: A PROGRESS REPORT

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JOB DESIGN RESEARCH: A PROGRESS REPORT

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THIS paper is concerned with, and reports the current status of, a developing research area and raises some questions about research in Industrial Engineering. Although the term job design has been in use since 1940, and has been more intensively repeated of late, there is still need for definition and for structuring of the research framework in Industrial Engineering within which such work is taking place.

The traditional role and objectives of Industrial Engineering have been methodology and technique development. This is partially an ends-means problem confronting all engineers, but has been a particularly severe one for Industrial Engineers. Parenthetically, failure to state ends has impeded progress towards professional status. The present trend in research is true to historical precedent with minor exceptions. Examination of recent research papers indicates continued concentration on methodology development with considerably more elegant solutions and sophisticated identification of problems. No value judgments are offered about this historic line of development. Among the purposes here, however, is to state the need for developing a framework of research upon which the practice of Industrial Engineering can progress. In this regard, more questions will probably be raised than answered, although in the specific research area of job design a formulation will be developed and available results reported.

INDUSTRIAL ENGINEERING RESEARCH

Industrial Engineers have been functioning for quite a long time and have made many significant contributions to the technology of production. However, they have left unsolved many problems of a vastly disturbing character to a highly developed industrial society. The time is long overdue to try to search for answers to these problems. Leaving the field of endeavor for what appears to be green fields of new technique development, as many in research are doing, is no solution. Cause for optimism exists, however, for research in Industrial Engineering is going on even if it is almost entirely restricted to universities. A first hand examination of what is going on in all the countries of western Europe, the cradle of industrialization, indicates an almost complete lack of such research. Examining the Industrial Engineering research scene reveals a not very different spectrum of efforts than may be expected in any applied science.research area. The work in progress is largely on the microscopic level and, as already indicated, largely devoted to technique development. Some of the exceptions here are the descriptive research going on in areas of motion study and human engineering. There is some work going on at the microscopic level being largely methodology development in operations analyses, or systems engineering. Notable by its absence is theory formulation, hypothesis development, and prediction; all necessary to development of research and to proper application of research results.

As designers and controllers of production systems, Industrial Engineers have given little to date towards the development of theories of production systems and sub-systems and of production organization. Within the self-imposed methodology limits, they have given greatly to the development of techniques that have made U. S. production systems, within the context of private enterprise management, the most productive in the world at present. The rest of the world is most intensively studying and copying those aspects of the present U. S. civilization which are most closely related to the Industrial Engineer's work; namely, production systems.

The outstanding class of unsolved problems confronting Industrial Engineers centers around the effective utilization of human resources in organizations. The context of this statement is not that engineers' effectiveness centers around needed human relations, knowledge, and skills; which is only partly the case, but that so little is known about the requirements and constraints imposed by the human linkages in production systems, that doubts are cast as to the effectiveness of these systems. This is indicated by the after-the-fact patchwork undertaken, such as the application of wage incentives, to make systems work. The fact that a system works, the proof of the practical man, is no test whatsoever. The human being is an extremely adaptable organism, and the probabilities are high that the human links in a system will sufficiently adapt to it to make it work, except under extreme circumstances. Some engineers have abandoned all hope in regard to developing knowledge of system requirements and constraints to maximize the effectiveness of human beings in industrial organizations, and they are waiting for the heaven of automation and peopleless organizations. Some are waiting for psychologists and sociologists to provide clear instructions as to how to proceed, forgetting that these specialists operate from different bases and concepts and are working towards different goals than the engineer. Some are pining for the "good old days" when financial incentives provided the all effective patch on the system that cured everything. Most engineers are living with these complex problems, and in a practical way are trying to carry out assignments and objectives given to them.

It must be remembered that the focus here is, of course, not on Industrial Engineering practice, but on research. Future practice depends upon present research, particularly if that practice has at its core the "design, development, and installation of integrated systems." In the context of utilizing human resources in designing integrated systems for the production of goods or services, the central need is the development of a field theory for the production organization with particular regard to the requirements, constraints, flexibility, and control imposed by the goal of maximizing the utilization of financial, facilities, materials, and human resources. Such theory is needed to give focus to research, to indicate direction, and to order and integrate research information already available, and to create a framework within which future research can be projected and research needs indentified. To maximize the utilization of human resources, knowledge is needed concerning the role and function assigned to members of the organization at all levels, as determined by system design and organization structure, the needed organizational relationships, communications network, reward system, etc.

THE JOB DESIGN RESEARCH ENDEAVOR

The grand objective of the job design research endeavor (hopefully avoiding scientism a la White's "Organization Man") is to conceptualize a theoretical framework leading to the development of a "science of human work." This is certainly not a new notion. The attempt is being made to create a scheme or framework built around the utilization of people carrying out the objectives of the production or service organization in regard to organization of work, jobs, functions, organization structure, communication network, control system, reward system, etc. This is not merely a problem in resource utilization presently amenable to solution in optimizing terms. Some may believe that the problems of concern here are on their way to obsolescence, if not solution, through the development of automatic production and data processing. On the surface, this would seem to be the case when the Daystrom installation for automatically operating a steam power plant is examined (*Business Week,* Nov. 22, 1958, p. 64). Assuming very widespread application to the production and data processing functions does not alter the needs discussed here. All that successful application of automatic processing signifies for the lowest levels of the organization is not that the problem has been eliminated, but that it will appear in other functions and at higher levels in the organization. In this sense the problem is merely being kicked upstairs.

Within the grand objective and restricted to specific research areas, the assumptions concerning the utilization of people which underlie Industrial Engineering methodology and practices need to be tested and validated, as well as have the limits of their effective application identified. Questions need to be raised that will help in the development of hypotheses for testing, and so aid in the building of theories. A few illustrative questions regarding long established methodologies are raised here as illustrations:

1. Concerning the application of Methods Study or Methods Engineering to maximize productivity:
   a) What are the limits of application as regards type of work, specialization, fractionation, and sub-division of activities?
   b) What is the relationship between motivations leading to effective worker performance, and specialization and fractionation of assigned activities?
   c) What are the consequences for effective performance of rigid work method specification, and what kinds and amount of methods variability may be permissible?

2. Concerning the application of Work Simplification, Suggestion, and Incentive Plans to maximize productivity:
   a) What are the underlying theoretical models for these plans?
   b) If the models are based on cooperative participation, what are the conditions for optimum participation that should be designed into plans?
   c) What positive or negative interaction exists between these plans as regards maximizing participation?

3. Concerning Work Measurement or Standards Engineering:
   a) What theoretical models underly each of the measurement techniques?
   b) What criteria are there to indicate the error limits permissible for various activities in various organizations?
   c) A variety of questions have been raised in the past by a number of authors, the bulk of which have not yet been adequately answered.

4. Concerning the application of Human Engineering data (man-machine system data) for effective equipment design:
   a) What is the transferability (what are the transfer errors) to industrial application of

laboratory data obtained from college students and military personnel under conditions of high motivation?

b) What is the transferability of data obtained on manipulating isolated devices when applied to complete operations and jobs?

5. Regarding the application of numerical methods of analyses to solving complex production problems, vigilance needs to be exercised in training and application to avoid having the application become a search for the panacea of mechanical answers to the problems of complex operations; all of which involve human relationships. To be avoided, because we can predict its failure, is treating these problems with a more sophisticated statistical version of old fashioned "Taylorism."

The job design research endeavor was undertaken as a specific choice affecting Industrial Engineering methodologies, and was estimated to provide the largest quantity of insights and hypotheses for theory building as concerns the design and operation of production organizations and systems, and their component functions, positions and jobs. Incidentally, the studies are concerned with problem areas representing the most serious short comings of present methodology. What follows here is a progress report of work done to date, and of studies started and about to start. The known data in this research area is not very large and has been publicly digested and redigested many times. Most of it goes back to precious few sources which are listed in the bibliography. A number of research studies are underway at different institutions, and significantly these are interdisciplinary efforts involving engineers and social scientists.

Of the many avenues of approach available in beginning studies, the decision was made to begin with the study of worker or clerk level jobs examining the effect of the contents of these jobs on worker productivity and attitudes. Such an examination reveals the functioning of the methodologies of Methods Study, Work Measurement, Plant Layout, Production Control, and Organization Design, and begins to provide the basis for examining limits and constraints. The decision to begin on the worker job level was made because such jobs are usually precisely defined, and the effects of changes can be more exactly measured. In addition, at this level can be seen in sharp focus, the full flowering of Industrial Engineering methodology as well as its shortcomings. The studies raise questions regarding the limits of application of the methodologies and bring into focus the specific problem of specialization as one of the factors defining limits of application. Beginning with the study of worker's jobs, future studies will be directed to higher organizational levels. Two studies under way at present are investigating both precisely defined jobs, and those having more variable routines, such as those of maintenance workers.

The studies are concerned with determining the requirements of organization design and operational effectiveness; particularly, its communication network and its division of duties, functions, and jobs in terms of maximizing the effectiveness of the designs of jobs at all levels in the organization. The goal here is specifying the requirements of man-organization-technology systems as concerns maximizing the effectiveness of the human linkage in these systems through the design of their jobs, functions, and assignments. For the worker job level, this can be seen as optimizing satisfaction of the requirements for maximum performance under the restraints of economy of utilization, i.e., specialization of technological processes and equipment, and of managerial planning and control. For supervisors and managers, the optimizing may be under the restraints of technology, functionalization, and centralized planning and control.

The specific immediate objectives are to discover what variations in job content and design effect relevant criteria of operational effectiveness of industrial and business organizations. Having begun investigating jobs and their design limits immediately adds other objectives which are social and behavioral. These are concerned with examining the consequences of highly specified and specialized jobs on effective performance of the individual, the department, and the organization, and on the total cost of operating the organization. The result is that job design research is in the good company of job enlargement, a term coined by Walker to describe actions taken by industrial companies to enlarge the scope of their production level jobs, as well as supervisory jobs,[1] in the attempt to overcome the negative aspects of extreme repetitiveness and specialization.[2]

The research results reported here are not recent. At present, it is too early to report results that studies presently under way will yield. Last year's A.I.I.E. National Conference Proceedings also carried a paper by Warren summarizing work done on this subject.[3] Four previous papers[4,5,6,7] have reported the work completed to date. A brief review is in order before going on to discuss additional studies.

RESULTS OF SYSTEMATIC STUDIES CONCLUDED

Studies completed to date fall into two broad groups, the first being sociological and psychological and concerned with examining the consequences for workers of job designs; the second group reports experimentation with jobs for the purposes of discovering operating variables and constraints.

In the former group any review must begin with the work of Walker and Guest,[8,9] who have been concerned with examining the consequences of job assignment and work organization on workers in the mass production industries. Significant for Industrial Engineers is that Walker and Guest find that workers on mass production assembly-line jobs despise their jobs in actively resistive ways. The strong dissatisfaction with the job, and frustration of aspirations, resulting from the job designs were not merely inconsequential side effects. There were some serious economic costs for the companies. Turnover was high, quality of performance was not maximized, and labor-management relations in formal (grievance procedure) and informal sense were in a constant state of tension.

These studies are consequential for the engineer in that they provide a focus on other psychological aspects of the highly simplified jobs, namely, "anonymity" and "depersonalization" which are direct consequences of organization, systems, and job design. The focus is important for it points in directions which may be highly amenable to investigation as contrasted with monotony and its consequent boredom, which previously was considered to be the villain blamed for the harmful effects of repetitive work. Enough research has been done on monotony to indicate that susceptibility to boredom appears to be unrelated to mental ability and is very much a question of individual differences, for a job is monotonous only if it is perceived as such.[10] An examination of "anonymity" feelings on part of workers leads directly into the area of Industrial Engineering decision making, regarding design of production systems and jobs. "Anonymity" results from designing out of the job virtually everything that might be of real, personal value to the worker as concerns (1) control over work pace, work methods, work variation, and work changes; (2) skills needed; (3) identity with product, process, quality, and other workers.

In the second group of studies, there are those that are experimental[6] and those that report controlled application.[11,12,13] The experimental studies are related to Walker's studies and others. Logically, they begin with an inquiry reported in 1955,[5] into how Industrial Engineers go about designing jobs by specifying its content and methods. This is particularly relevant to examining the methodology and limitations of Methods Study. The results of this inquiry are known and are not surprising, even if somewhat disappointing, for they revealed no clearly developed theories, nor design principles, and indicated that decisions were made based upon the very limited criterion of minimizing immediate costs of operation (as interpreted through minimum unit operation time). Although job satisfaction was reported as a requirement for job design, no criteria were used to determine that the job design was satisfactory to workers.

The next study in the sequence[14,6] was concerned with examining the notion of "over-specialization" of mass production jobs by enlarging these jobs both in work content and responsibility, and evaluating the consequences in terms of the quantitative measures of output and quality, and the subjective measures of attitude towards the job and job satisfaction. Increases in responsibility and work content resulted in a marked increase in quality without a loss in quantity of output, as well as positive changes in attitudes toward the job and in job satisfaction. The results were achieved after a very short interval of experience with the very greatly enlarged job as compared to the previous assembly-line job design. For this reason, the results of this study can be taken as only indicative that there is a point of diminishing returns to specialization and fractionation of jobs. A conclusion that can be drawn, which is not premature, is that worker needs with regard to the work itself may be as important as are financial, security, and status needs.

Many questions were left unanswered by this study including an examination of the effects over long periods of time of such changes on quantitative criteria of output, quality, costs, etc. Plans are under way to have studies similar to this one conducted with the changes remaining in effect for a substantially long time period. The study also indicates the problems that lie ahead in conducting research in job design.

FUTURE STUDIES

It is difficult, and perhaps dangerous, to publicly outline research studies in detail prior to conducting them, since many modifications in plans take place of necessity. This is particularly so in an area where the variables are so complex and affected by individual differences and by possible experimental contamination brought on by the need for collecting data on actual operations in the field. In 1955,[5] the following was predicted as to the research approach that would be needed:

> "The nature of job design research and experimentation should reflect the multi-dimensional character of the problem . . . . Paramount among the requirements is that job content must be the central theme of all experimentation with other variables included in various experimental designs. In addition, multi-dimensionality and interaction among variables calls for a problem-centered research-team approach . . . ."
>
> ". . . . Obtaining the data needed will require that studies be conducted that will range from determining and measuring "meaningfulness" as applied to operations, work methods, work

groups and jobs through the determination of long term total economic cost criteria, to the determination of the means of designing processes, systems, methods and product components in terms of job needs."

Ranking prominently among future studies are those concerned with criteria identification. The need to develop useful criteria to measure effectiveness of job design is of utmost importance if any sound use is to be made of research findings by managers and engineers who are not primarily concerned with doing good nor with providing means for job satisfaction, but with the problem of optimizing the utilization of human resources. Not since 1924, when P. S. Florence[15] presented a treatise on the economic cost of fatigue and unrest, has much consideration been given to developing cost criteria for decision making in regard to job organization.

The experimental study previously reported[14,6] confirmed the necessity of using total cost criteria. While average unit performance time at the end of the experiment was the same as on the previous assembly line method, a 75% reduction in defects took place accompanied by rising average output.

Studies under way, at present, are fairly well focused around the identification and testing of criteria, and factors affecting criteria, as well as development of suitable measuring instruments. It is becoming apparent that it may not be possible to use a single valued criterion and that the criteria that are developed will be complex, with productivity as one of the factors. For individual companies a single valued criterion may be derived by weighing sub-criteria or factors. Criteria development is being undertaken under two sets of conditions, and in both cases long-term effects are being considered. First, a priori criteria are being evaluated as to their sensitivity in determining the effects flowing from fractionated and specialized jobs as compared with similar jobs that have been modified by companies in the direction of increasing the spectrum of types of work, skills, and responsibilities contained in the jobs. This evaluation will be done with the low skilled production worker's jobs and with skilled maintenance worker's jobs. Second, using the evaluations of the prior study highly fractionated production worker's jobs, of a mass production variety, will be modified in specific experimentally chosen directions and compared over a long time period with non-modified jobs as controls. In both situations, the criteria related problems of determining means for identifying worker perception of the job as to variety, skill, content, responsibility, organizational contacts, etc., will be undertaken. It is anticipated that significant relationships may exist between these perceptions and total economic or long term cost criteria. To secure further insights leading to possible answers as to why productivity and quality increases have been obtained as specialization and fractionation have been reversed, attitudinal and perception scales for evaluating job "meaningfulness" and "responsibility and control" will need to be developed. If these instruments can be developed, they will be used with jobs having varying degrees of rigidity in regard to job specification, i.e., content rigidity as well as varying degrees of specialization.

A related analytic study important to further job design experimentation, as well as production systems study, is concerned with classification and definition of systems of production technology as concerns types and degrees of rigidity imposed on job content, communication, control, etc. It is important that knowledge be available concerning the limitations imposed by different production systems on opportunities for content and methods variability of worker, supervisor, and middle manager jobs. What areas of freedom are permissible in discharging duties, and what constraints are imposed on decision making of these line members of the organization by technical decisions made in the design of the production system? What aspects or parts of the system impose the limitations, and at what organizational level? Such information will aid in understanding the nature of jobs as well as permit predictions to be made in regard to responsibilities, planning, and control; and communication needs imposed by production system design.

For the far future, studies are being considered that will examine the jobs of foremen and supervisors, followed by those of managers. Eventually, it should be possible to put together the requirements and constraints needed to establish specifications for the design of production organizations.

CONCLUSION

Interest in job design is widespread among social philosophers in our society and recently has become a subject greatly discussed among managers of American business and industry. [17, 18, 19, 20] To date, there has been no great interest kindled among engineers and personnel concerning an examination of currently accepted production systems to re-evaluate the means of optimizing the utilization of the organization's human resources.

The successes of a few companies in securing increases in worker productivity and product quality by enlarging either the work content of jobs or of responsibilities through "job enlargement" is attracting a great deal of attention. In Western Europe, the results of job design studies completed to date and reports of job enlargement are being received with high enthusiasm; that is, if the author's sample of some 2,000 engineers and managers with whom discussions were held in eleven Western European countries is indicative. This enthusiasm, perhaps, reflects Europe's traditional conflict of needs and values. On the one hand, there is a strong desire, as well as strenuous attempts being made, to adapt the U. S. system of production and secure the benefits such a system bestows. On the other hand, there is great resistance and hesitation because of a strong desire to avoid the system's dehumanizing aspects.

There are numerous problems confronting the researcher in job design, not the least of which are the hazards of pioneering in marking out the problem area and developing suitable means of investigation. Realistic results demand making studies under realistic conditions and plant sites are difficult to obtain, under the conditions of unpredictability of results. However, there are proving to be enough interested managers in industry so that sites are being made available. Research in real plants with real workers always presents the hazards of contamination and the "Hawthorne" effect, requiring carefully controlled studies.

These problems are perhaps not as great as those growing out of the current phenomenon at universities of competition for research attention between the research problems of importance to a professional discipline and its faculty, and those of interest to the military and other government agencies capable of offering substantial contracts to support research. The competition sets up unnecessary and undesirable competition for graduate students, most of whom need the financial assistance available by associating with sponsored projects. Business and industry could help greatly in this regard by offering assistance to Industrial Engineering research by both conducting some themselves, and by establishing graduate fellowships and grants-in-aid to qualified graduate scholars.

Lastly, the magnitude of job design research, because it is problem-centered rather than subject-centered, presents a number of problems centering around the compartmentalization of knowledge existing in universities and in industry. It is quite difficult to carry on interdisciplinary research in the climate existing in universities at present. Perhaps Bellman[21] states this more eloquently:

> "Yet the narrow parochialism of the modern university—oh, ironic title!—hardly allows this. The emphasis upon facts rather than ideas, upon subjects rather than problems, effectively rules out the 'systems' approach so essential in the study of any significant situation."

The situation will undoubtedly improve, for there is a slight trend in the problem-centered direction. Presently, however, each subject specialty is burrowing deeper in very narrow areas, which is good, but the questions and problems that cross subject areas are being left alone. This is particularly the case when the subject areas have not been closely connected in the past. Crossing subject areas simply slows progress somewhat until adequate knowledge in related subjects is acquired.

As indicated earlier in this paper, knowledge of job design in terms of tested data is very meager at present, despite long stated concern about the effects of modern production systems on the individual as a member of the organization and of society.

In concluding, it may be well to summarize the objectives of the job design research endeavor. The long range objective is to determine the requirements of the organization's design and operational effectiveness, particularly its communication network and its division of duties, functions, and jobs in terms of maximizing the effectiveness of the design of jobs at all levels in the organization. The goal here is that of systems design, i.e., specifying the requirements of man-organization-technology systems as concerns maximizing the effectiveness, considering the requirements of the individual and of the organization, of the human linkages in the system through the design of their jobs, functions, and assignments.

A related objective is to develop at appropriate stages, general principles of job design and organization design based upon empirical results obtained in the studies. The principles to be developed can be thought of as restraints or parameters to be satisfied in designing effective organizations, production systems, functions and jobs, such as are being made necessary at present by the advent of automation technology. Validated principles will be used to attempt to formulate comprehensive theoretical models useful for the design of jobs, functions, organizations, and communications networks as well as such systems as production planning and control, incentives, personnel placement, etc.

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section 28

SIMULATION RESEARCH IN SHOP SCHEDULING

by **RICHARD W. CONWAY, BRUCE M. JOHNSON**
and WILLIAM L. MAXWELL

RICHARD W. CONWAY is Assistant Professor of Mechanical Engineering, Department of Industrial Engineering Administration, Cornell University.

He was born in Milwaukee, Wisconsin and attended public school there. He received the bachelor's degree in mechanical engineering and the doctor's degree from Cornell. He has been employed by Cutler-Hammer, Inc., and Nordberg Machinery Company and has served as consultant to the Operations Research Office of the Johns Hopkins University, The General Electric Company and the International Business Machines Corporation.

He is at present director of a research project sponsored by the office of Naval Research at Cornell.

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He was born in New Brunswick, New Jersey and attended Rutgers Preparatory School in that city. He received his bachelor's degree in mechanical engineering in 1955 from Rutgers. He has been employed by Cornell University both as a teaching assistant and a research assistant.

He is at present a candidate for the doctor's degree in Industrial Engineering.

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He was born in Philadelphia, Pennsylvania and attended public school there. He received the bachelor's degree in mechanical engineering in 1957 from Cornell. During his undergraduate study he was employed by the Philco Corporation under the Cooperative Engineering Education Plan. Since his graduation he has been employed by the Carborundum Company as an operations research analyst.

He is at present a candidate for the doctor's degree in Industrial Engineering.

SIMULATION RESEARCH IN SHOP SCHEDULING

by Richard W. Conway, Bruce M. Johnson, and William L. Maxwell

Department of Industrial and Engineering Administration, Cornell University

I. The Problem

- A. Characteristics of a Production Shop
    - Dimensions
    - Disciplines
    - Load
        - Method of release
        - Balance between machine centers
        - Flow characteristics
    - Measures of performance
        - Amount of in-process inventory
        - Satisfaction of completion-time requirements
        - Rate of thru-put
- B. The Scheduling Problem
    - Status of practice and theory
    - Important Questions

II. An Experimental Investigation

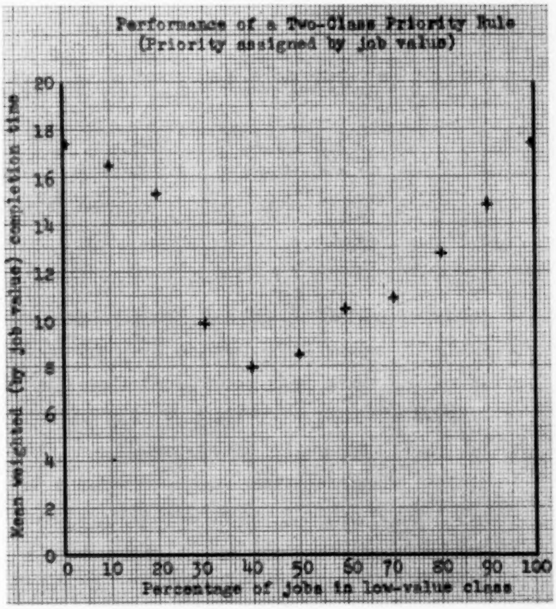
- A. Research by simulated experimentation
- B. The CORNELL RESEARCH Simulator
    - A general purpose queue-network simulator for the I.B.M. 650
- C. The design of an experiment

III. Experimental Results

- A. A Comparison of Priority Dispatching Rules

    Comparison of various simple priority rules with respect to in-process inventory, satisfaction of completion-time requirements, rate of thru-put.

    Typical of the results presented is the information in the figure below. A portion of an investigation of priority rules that rank jobs into one of two classes according to value, this figure shows the effect upon the mean weighted (by job value) completion time of changing the proportion of jobs in the low-value class.



- B. Development of a dispatch rule with "foresight"
- C. Investigation of changes in shop discipline

IV. Conclusions

- A. Scheduling
    - Practical significance
    - Areas for investigation
- B. Simulation
    - Prospects and Problems

(This paper was not ready in time for inclusion in the Proceedings. Copies may be obtained on request from the authors.)

OPERATIONS RESEARCH AIDS MANAGEMENT

by **ROBERT G. BROWN**
Director
INVENTORY CONTROL STUDIES
ARTHUR D. LITTLE, INC.

A graduate of Yale in Engineering, Robert G. Brown received his M.A. degree in Mathematics from his alma mater in 1948. That year he joined the Navy's Operations Evaluation Group in Washington, D. C. In 1950 he went as research engineer to Willow Run Research Center of the University of Michigan. There he supervised the design of a large electronic data-processing system and its evaluation under operating conditions. He also headed the Operations Research Department of the Research Center and served as project engineer on research and development for the Air Force.

Since 1953 he has been a member of the Operations Research Group of Arthur D. Little, Inc. of Cambridge. He has directed work for a wide variety of clients and has been responsible for developing and coordinating all of the research on inventory control, production planning, and related problems. He is the author of several technical papers on the solution of inventory control problems and has recently written a book on statistical forecasting.

Mr. Brown is a member of the Operations Research Society of America, the American Society of Mechanical Engineers, the American Mathematical Society, the Mathematics Association of America, and the Association for Computing Machinery.

OPERATIONS RESEARCH AIDS MANAGEMENT

by Robert G. Brown

Director, Inventory Control Studies,
Arthur D. Little, Inc.

IN THE PAST ten years there has been a spectacular growth in the development and use of objective decision rules for controlling inventories of finished goods in the field, of parts and assemblies in the factory, and of raw materials. This development has been sparked by the advent of high-speed, internally programmed, electronic computers. Not only can the computer economically keep track of the stock on hand and the stock on order, but also it can be made to "decide" when to place a replenishment order and how large that order should be.

An inventory control system may be very simple or it can be quite elaborate. Any system, however, can be thought of as essentially an integrated system of rules for deciding *when* and *how much* to reorder. There are many examples of recent developments in the theory of inventory control that can be found in the literature.[6,7,8]

INVENTORY MANAGEMENT

There has been relatively little work done on providing rules for managing the inventory control system. The sales manager, the controller, and the plant manager may find themselves in the position of having a high-powered and sensitive device for controlling inventories without having been taught how to use it effectively. It is as though they were given a modern automobile to drive by intuition.

A good inventory control system should handle automatically all routine situations that arise. Thus management has the maximum time available for planning the future of the business and for dealing with the emergencies and special situations that arise.

For example, in the spring of 1959, many manufacturers are concerned with ordering sufficient steel to last through a potential strike and the concomitant disruption in deliveries. A well-designed inventory control system should help management plan the quantity of steel needed and relieve management from the pressure of dealing with the routine current operation of the business.

Industrial engineers and men in operations research have been doing a very good job of developing the control system that will handle the routine functioning of the business. In this paper I want to describe work in two particular areas that can help manage the control system. The first is the problem of setting values for policy variables that appear in the rules for controlling item-by-item inventories. The second is the responsibility for monitoring the control system to make sure that it is conforming with established policy and to decide whether the system should be modified in any way to take account of new developments.

THE LOGNORMAL DISTRIBUTION

The rules used to decide when and how much to order for any one item can be expressed as equations involving policy variables—such as return on investment, or desired customer service—and the annual sales rate of the item. These equations can be manipulated to estimate the average investment, the annual cost of ordering, and the average fraction of the time that a customer may expect to find the item in stock.

If we knew how many items there were in the product line that sold $10 a year, or $100 a year, or $1,000 a year, or any other quantity, we could add up these equations to estimate the *total* inventory, the *total* ordering cost, or the average service rendered by *all* items.

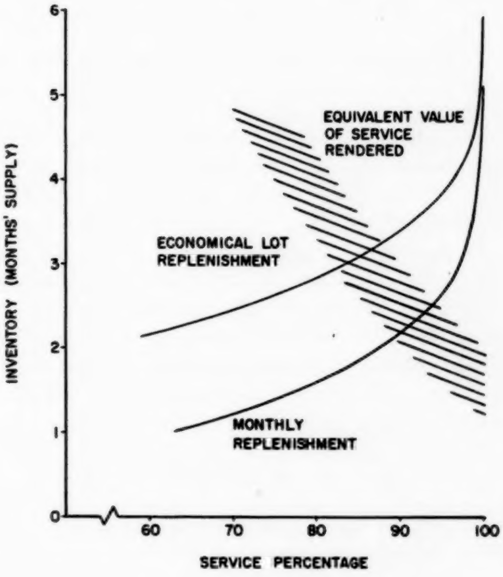


Figure 1

The Total Investment Needed To Render Service

For example, we could write down an equation that gives the inventory investment necessary to support any desired level of service.[2] Fig. 1 is a typical plot of inventory as a function of service, which should help management establish a reasonable service policy.

The ability to express total costs and investment by an equation should help management in setting a reasonable value for any of the policy variables that appear in the equation.

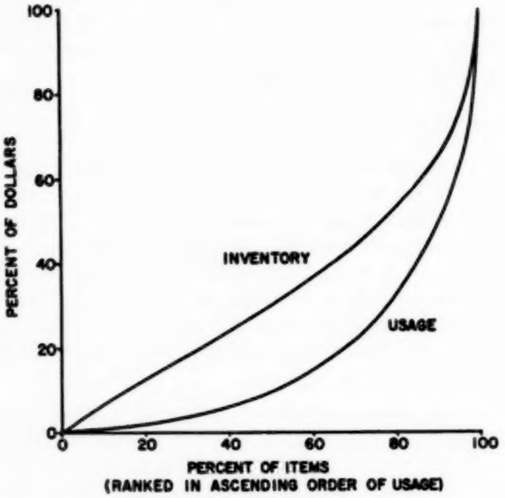


Figure 2

Distribution of Income and Investment For Commercial Sales

The derivation of these equations depends on the number of items having each of the possible dollar sales rates. In working with more than 40 corporations, I have observed that the logarithms of the dollar sales rates are normally (Gaussian) distributed. We say that the sales rates have a lognormal distribution.[1]

Furthermore, we notice that the standard deviation of the logarithms of the sales rates is always *ln* 10 for items sold to other companies and *ln* 2.5 for those sold to consumers.[2]

The lognormal distribution makes it easy to estimate the result of summing an equation across all items in the line, because of the relationship

$$\overline{x^k} = \overline{x}^k e^{k(k-1)\sigma^2/2}$$

where σ is the standard deviation of the logarithms of the sales rates.

For example, the value of a lot for one item can be written as

$$q = \lambda\sqrt{s}$$

where $\bar{s}$ is the annual dollar sales rate of that item and λ is a parameter that includes both the costs of acquisition and the costs of carrying. The value of the cycle stock component of total inventories is

$$Q = \frac{N\lambda}{2}\sqrt{\bar{s}}\; e^{-\sigma^2/8}$$

where N is the total number of items in the line, $\bar{s}$ is the average dollar sales per item and

$$e^{-\sigma^2/8} = 0.515$$

for sales to other companies, or 0.900 for sales directly to the consumer.

The fact that the sales rates are lognormally distributed leads to the familiar Lorenz curves (Figs. 2 and 3) that show the percent of items accounting for a given percentage either of income or of inventory. References (4) and (7) deal at length with systems of inventory control based on devoting more attention to the few items accounting for the largest number of dollars.

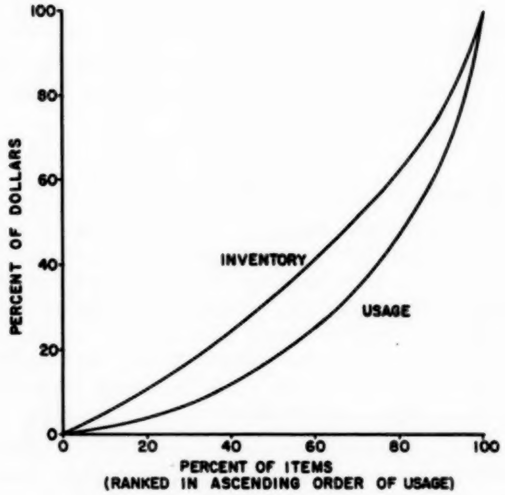


Figure 3

Distribution of Income and Investment For Retail Sales

SETTING POLICY VARIABLES

The recognition of the lognormal distribution, coupled with an understanding of the basic equations covering cycle stock and safety stock, make it possible to draw a curve like Fig. 1. Quite a bit of information can be drawn from this figure. First, it is possible to compare the proposal for replenishing stock in economical lot sizes against the proposal to replenish usage on everything every month. (Of course, the out-of-pocket costs would also have to be compared before deciding between these alternatives.) Second, if the company is now operating at a service level of about 80%, it should have about 1.6 month's supply of inventory on the monthly replenishment system. The cost of increasing performance to 90% service would be an extra 0.6 of a month's supply investment. If we knew, as we do in some cases, the value of rendering better service, indicated by the shaded region in Fig. 1, we can conclude that 90% service is worth the cost of getting it. On the other hand, if we do not know the value of rendering better service, management can at least weigh the explicit cost of better service against a subjective estimate of the value and therefore arrive at a reasonable decision.

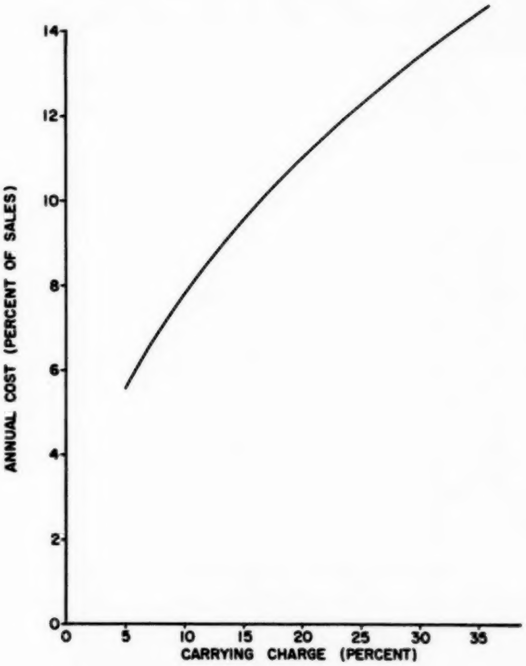


Figure 4

Change in Ordering & Setup Costs as Affected By Carrying Charge

Another problem that frequently arises in designing an inventory control system is to find the rate used as a carrying charge on inventory. There are many lines of argument, one being that this charge is a convenient mechanism for management to secure an acceptable balance between the out-of-pocket costs of ordering and setting up production runs against the total investment. Figs. 4 and 5 show how these two factors depend on the value used for the carrying charge.

MONITORING THE SYSTEM

From time immemorial, management has been plagued with the problem of deciding how much inventory it should carry. Unfortunately, the accountants have come to use "turnover" as a guide to the appropriate inventory level.

Turnover, which can also be expressed as a month's supply of inventory, is a very dangerous yardstick, particularly in times of changing conditions. If you change either your total dollar sales or the number of items you carry in inventory, the turnover must change if you expect still to get a balance between investment and ordering costs on the one hand, and between investment and service to customers on the other.

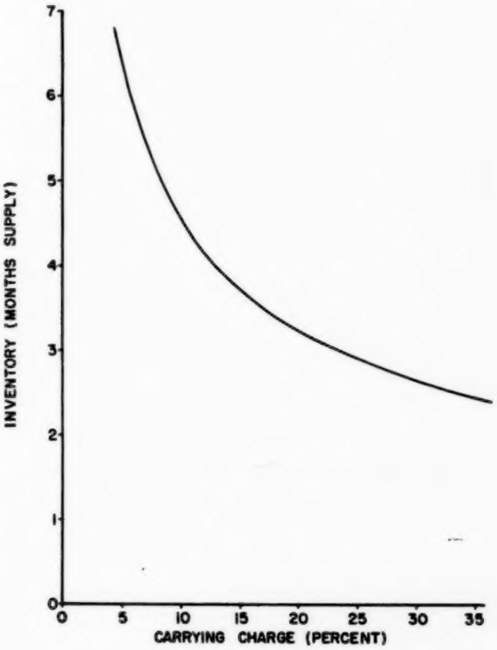


Figure 5

Change in investment as affected by carrying charge.

Fig. 6 shows a simple control chart that can be used to aid management in recognizing the appropriate level of inventory. The two curves show the average inventory expressed in months' supply for an actual system.

Let us suppose that in 1957, the company sold an average of $200 per item carried in stock. If they aim at between 90 and 95% service, they should have carried a two months' supply or a six times turnover. In 1958 when the product line expanded slightly and sales dropped off due to the recession, the sales were only $100 per item stocked. Therefore, the inventory must go up to at least two and a half months' supply or service will suffer.

Finally, we come to a typical question of reporting. Most controllers like to have a report of the inventory value at the close of each accounting month. The simple number $51,876,213.22 by itself tells management nothing about whether inventories are too high or too low. We know, based on a curve like Fig. 6, that there is a par value for the inventory investment. There is a standard inventory to which management is committed by the decisions they have made in setting values for the policy variables. We also know that inventories are subject to fluctuations around the standard value. A well-designed inventory control system must be able to cope automatically with reasonable fluctuations in inventory levels.

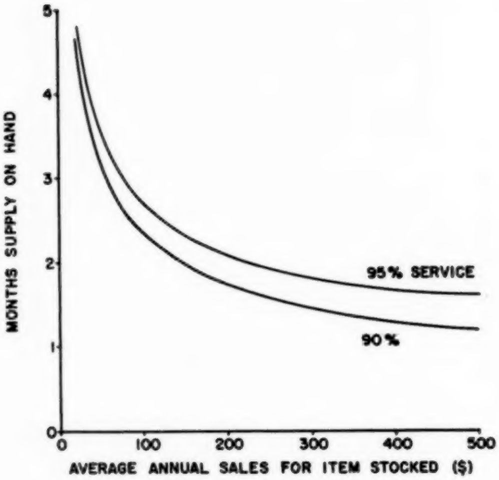


Figure 6

Standard inventory Levels for different locations.

It is possible to derive an expression for control limits that expresses the maximum and minimum reasonable levels for current inventories.[3] In Fig. 7, for example, we see that although the inventory has varied from a low of $40,000,000 to a high of $67,000,000, it has always been within the limits computed ahead of time that express the range of variation with which the system can cope automatically, requiring no management intervention.

CONCLUSION

Let me urge, then, that when you design or modify your inventory control system, you keep certain objectives before you:

(a) Develop formal decision rules to answer "when" and "how much" routinely for each item. If you are using a computer, take advantage of its speed, capacity and flexibility to make the routine decisions automatically. If your system is still manual, the formal rules will still make for better control.

(b) Also develop the equations that express total investment, total out-of-pocket costs and average service in terms of the policy variables, so that management can set reasonable values for these variables. The lognormal distribution of sales rates should make it quite easy to develop these guides from the equations used for the item-by-item decision rules.

(c) The periodic reports to management (investment, service, production backlog) should show not only the actual, but also a standard that reflects the values set for the policy variables and a tolerance range within which the system can cope without intervention.

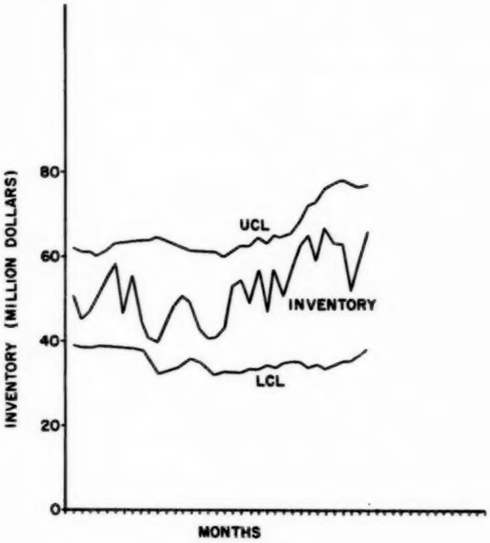


Figure 7

Control limits for normal inventories.

With these guides management can move quickly when circumstances warrant, but avoid the danger of compromising the good features of your system, which the traditional standards (such as turnover) can lead to.

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INDUSTRIAL ENGINEERING — A NECESSITY FOR EFFECTIVE RETAILING

PART I
by E. Wesley Green
Methods Division Manager

PART II
by KATHERINE E. FOSTER
Management Technician

SEARS, ROEBUCK AND COMPANY

Upon receiving his discharge from U. S. Army, Mr. Green entered Georgia Tech, and in 1949 graduated with a degree in Electrical Engineering. He then worked as an insurance company safety engineer for four years; the last two as Branch Engineering Manager for eastern Tennessee.

In 1953 he re-entered Georgia Tech to study Industrial Engineering and received his Bachelor's degree a year later; subsequently in 1955 he received his Master's degree in Industrial Engineering from Ga. Tech.

Mr. Green combined part-time teaching in the Georgia Tech evening school with his activities as an Industrial Engineer at Sears until the summer of 1957.

Mr. Green has been associated with Sears since 1955 and has served in his present capacity as Methods Division Manager for the last two years. As Manager of the Methods Division he is responsible for all phases of Industrial Engineering in the Atlanta Mail Order Plant which employs three to five thousand people, depending on the season of the year, and occupies approximately 1,500,000 square feet of floor space in two buildings. In addition, the training of new employees and the publication of the house organ are a part of the Methods Division activities.

Miss Katherine Foster is a Management Technician in the Atlanta Mail Order Plant of Sears, Roebuck and Co. She is a native Georgian and a graduate of LaGrange College, LaGrange, Georgia. While in college she was a member of many social and honorary societies and served as an officer of her class. She is listed in Who's Who in American Universities and Colleges. She was awarded a Bachelor of Arts Degree, with mathematics and general science as her major and minor studies.

Miss Foster joined Sears as a member of the Methods Division in 1944. Since then, she has specialized in the application of Industrial Engineering techniques to clerical activities, and was associated with Sears, Roebuck and Co. Research and Development Department in the development and installation of that company's first standard cost system for non-manufacturing operations.

INDUSTRIAL ENGINEERING — A NECESSITY FOR EFFECTIVE RETAILING (PART I)

by E. WESLEY GREEN

Methods Division Manager—Sears, Roebuck and Co.

WITHOUT a doubt, I have the most enviable part in the Conference program; and—I might add—in certain respects, the most challenging. Enviable? The reason is obvious: To have an opportunity to speak before a group as attractive as you are is certainly a great pleasure. Challenging? Because the purpose of this technical session is to acquaint you with the American Institute of Industrial Engineers and Industrial Engineering in a retailing organization. In a period as short as this, it will be difficult to do more than provide you with a passing acquaintance with these subjects.

Some of you probably saw the brochure which was mailed out in March in which the title "Now You'll Know" was listed for the ladies technical session. I want to be sure we understand at the outset that I'm not going to give away any of our secrets. So perhaps "I'll Never Tell" or "You'll Never Know" would be a better title . Perhaps I shouldn't be quite so definite about this because we are also going to hear from one of my associates at Sears, Miss Katherine Foster, who will help in telling you this story. So perhaps "Now You *Will* Know", after all.

It seems to me that before we get into any discussion of Retailing we would profit by a brief look at the history of Industrial Engineering generally, and of the American Institute of Industrial Engineers specifically. This should permit a better understanding of the relationship of Industrial Engineering to the retailing business. Most of you probably already know something of the history of our profession: Its origin dates back to the 1880's when Frederick W. Taylor approached the problem of what constitutes a day's work. He endeavored to answer this question by determining the time necessary to do various jobs. This was actually the beginning of time study. Taylor's experiments in the determination of optimum cutting speeds for cutting various metals, and the effect of fatigue on men who handled pig iron are examples of the contribution he made in standardizing work. His work marked the beginning of Scientific Management—an approach to management which promoted (and still does) the following principles:

(1) Science—not rule of thumb management, (2) Harmony—not discord between management and managed, (3) Cooperation—not individualism, (4) Maximum output—in place of restricted output, and (5) The development of each man to his greatest potential.

Shortly after Taylor had done his initial work, others, including Frank B. Gilbreth and Henry L. Gantt, began doing research and developing additional techniques for increasing the productivity of our young nation. Gilbreth, who is known as the "father of motion study," is known for his development of micromotion study by which motions are broken down into basic categories to permit minute examination of a method of performing work. It was he who began the development of the principles of motion economy. I am sure most of us are familiar with his use of motion study in developing the one best way for laying bricks. And—very important—it was he, with the help of his wife, who really made it possible to accomplish the second of the five objectives previously discussed: Harmony—not discord between management and managed.

A word more about Mrs. Gilbreth, who continued the work Mr. Gilbreth had started. She is a trained and well educated psychologist who played a large part in Mr. Gilbreth's consideration of the human being in his early Industrial Engineering work.

I recall having heard a story about her which is indicative of her graciousness and humanity. Dr. Gilbreth came to Atlanta a few years ago for a speech at a Ladies Night Meeting of the American Institute of Industrial Engineers. As you know, Dr. Gilbreth is recognized for her work in connection with the Heart Association in the development of well designed and equipped kitchens for heart patients. The family with whom she was to stay here in Atlanta were somewhat disturbed since they felt that their kitchen was not arranged as well as it could have been, and were somewhat apologetic about this during the first evening of her stay. Their fears were immediately dispelled when her comment was something to the effect that her kitchen was the biggest mess in the world.

She was, and is, recognized as an outstanding proponent of scientific management and is a credit to the profession and to womanhood.

Gantt, who was a close associate of Taylor for a number of years, is credited with the development of wage incentive systems, although Taylor had started a bonus plan for production workers prior to that time. He added another important facet of scientific management—that of planning and control charts.

There were many others who helped to make Industrial Engineering a true engineering profession, but to recount their contributions would resolve our discussion exclusively into a history lesson. That we cannot do.

I don't mean to imply here that Industrial Engineering did not have problems during this growth period, for there were many. As a matter of fact, the name, Industrial Engineer, did not come into being until World War I. It was at this time, and in the years following World War I, that we had our greatest problems—half trained and half-baked Industrial Engineers sold management a bill of goods—that they were the answer to a maiden's prayer, so to speak. The truth of the matter was that they were only interested in promoting themselves. Management, supervisors, and workers were a means to an end and were exploited for all they were worth. It is a tribute to the courage and tenacity of a few dedicated and progressive Industrial Engineers that our profession has gained the stature which it enjoys today. We can be thankful, too, for the part professional societies have played in our development.

GROWTH OF THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS

You may be interested to know that there have been only three recognized professional societies in the development of Industrial Engineering. At one time there was an organization known as the Society of Industrial Engineers; another was the Taylor Society, named for Frederick W. Taylor. These two merged into the Society for the Advancement of Management.

The American Institute of Industrial Engineers arose from the fact that included in the membership of the Society for the Advancement of Management were representatives of other professions as well as Industrial Engineering. There was a need then for an organization dedicated solely to the service of the Industrial Engineer. The A.I.I.E. was organized by a few far-sighted individuals who recognized this need. Surprisingly enough, the Institute was formed less than twelve years ago—on January 12, 1948, by a group of twelve people in Columbus, Ohio. Four months later the membership stood at 938 student members and only 341 active members. The treasury showed a balance of only $860 after a year of operation. We can be justly proud of our growth in these few years. We now have an active membership of more than 10,000.

The requirements for membership are strict and the foundation of the Institute, its constitution and by-laws are sound. Thus we feel that the strength of the organization has not suffered from this rapid, world-wide growth. Perhaps one reason for this is the quality of the leaders during these formative years. All of our presidents have been exceptionally capable people, beginning with Dwight D. Gardner, our first elected president. George Gustat, who got the conference off on the right foot this morning by his wonderful keynote address, is another example. I am sure also that we are destined for a banner year ahead because our new president will extend the precedent of top-notch leadership established in 1948 and continuing to the present time.

The sound growth of the American Institute of Industrial Engineers can also be traced to the objectives which have guided the Institute from the beginning. Initially these objectives were (1) to raise the professional standards of Industrial Engineering, (2) to assist colleges and universities teaching I.E. subjects, and (3) to serve as a clearing house of information for State Registration Boards. The acceptance of Industrial Engineering as a recognized field of engineering with the same status as mechanical, electrical and other engineering fields, and the high percentage of Registered Professional Engineers among our members are indicative of how well these objectives are being achieved.

Too, we are adding to our fund of knowledge and to our effectiveness by the comparatively new tools such as operations research and electronic data processing. A brief look at the program for this conference and at the programs of earlier A.I.I.E. conventions will reflect the expanding horizons of Industrial Engineering. Adequate educational facilities and competent educators are basic to this continued expansion—and fortunately we can point with pride to representatives of the educational institutions who are among the conferees here this week. I am very proud to be able to count myself among those who have had or now have a part in adding to the knowledge of budding Industrial Engineers.

SEARS, ROEBUCK AND CO. ORGANIZATION

I am proud also to be here this morning as a representative of the foremost retailing organization in the world. The British used to say that the sun never sets on the British Empire. This can almost be said for Sears, Roebuck and Co. Sears stores are located all over our nation; there are branches of our company in Latin America; and Sears is represented in Canada and in Australia by Simpson-Sears, Ltd.

Why do I give you this information? Because if we are to understand the concepts of Industrial Engineering as practiced in retailing, and more specifically at Sears, we should know something about the company in addition to having some knowledge of Industrial Engineering.

As we mentioned, Sears is a large organization—but we will be talking about only one segment of the company operations: the Mail Order business. It might be interesting to you (I know it was to me) to know that Sears Mail Order Plants and the retail stores do not operate under one local management. For instance, here in Atlanta we have the mail order plant and a retail store housed in the same building. But we in mail order report to our General Manager, Mr. C. O. Jenkins. On the other hand, people who work in the retail store report to their own manager.

It is necessary, also, that the accounting functions be maintained on a separate basis in order that the officers of the company can evaluate the contribution of each branch of the company to the total profit. This separation of accounting explains why some of you may have had some trouble in obtaining an adjustment in a retail store on merchandise purchased through a mail order plant. If established procedures are followed, this shouldn't happen, but occasionally it does.

Of course, as we progress upward in the organization chart, we find one person who is responsible for the operation of both retail and mail order. This is the territorial vice-president. In the South, he is Mr. L. E. Oliver, whose responsibilities include three mail order plants—Atlanta, Greensboro and Memphis—and 95 retail stores in eleven states.

MAIL ORDER OPERATING PROCEDURES

Have any of you ever wondered what happened to an order you have mailed to us, or which you have placed at a Catalog Sales Desk? It is in the processing of your orders that Industrial Engineering plays a part. It would be nice if we had a couple of hours to walk through the many departments which have a part in this processing. However, as a substitute for the tour, perhaps we can get an idea of what goes on behind the scenes by viewing this series of slides.

Here we see the beginning of the process. Mail is received each morning in the mail opening department and weighed to give us an idea of the number of orders we must process during that day. The envelopes containing orders are opened by first shaking the contents to one end of the envelope and then running them through this slicer.

They are then distributed to the mail openers in batches of 60 each—this is the way we keep production records for these girls who are on incentive. The girls scan the order to determine whether it is a single or a mixed order. To clarify the terminology—a single order is for merchandise from only one department. A mixed order is for merchandise from two or more departments. We will limit our discussion to the handling of mixed orders since this type represents the greater volume of our business. When this sort between mixed and singles is made, the clerk attaches necessary labels and places the order form in a wrapper. The wrapper serves two purposes—first, as protection for the paperwork, and secondly, as an indication of the priority to be given for subsequent handling. To establish this priority, the wrappers are color coded to indicate the day of the week on which the order is received.

The next operation is called cash registration. It is just that. The amount of cash enclosed, or in the case of a C.O.D. or time payment order, the value of the order, is registered on the order form.

Separate entry tickets, one for each item ordered, are created on these machines. By so doing we are able to fill all items on the order at the same time and thus cut down on the overall time necessary to process the order. The alternative to the creation of the entry tickets would be the movement of the customer's order from one department to another until all items ordered had been filled. I am sure you can see the problems in time and equipment such a system would encounter in a multi-story building such as ours.

Indexing customer orders is the next step. In this operation the date and amount of each customer's order is recorded on addressograph plates. The sole purpose of this activity is to provide the necessary information for distribution of catalogs. The frequency with which a customer orders and the value of the order determine whether or not the customer receives a catalog. The index, which contains well over a million names, is really a huge mailing list. By the way, as the order is indexed, the customer's name and address are scribed on the label on the addressograph machine.

The next step in the process is perhaps the most important in the system. It is in this department that the orders and entry tickets are scheduled. Each order and each ticket of that order receive the same schedule impression. This becomes the customer number and permits the ultimate match-up of all items for an order at the packing beach.

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      14
518    5   10:40
       8
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The first three digits represent the number of the bin into which the packer sorts all items of this customer's order. Of the three middle numbers, the top one is the date; below this is the month; and at the bottom the identity of the machine on which the order is scheduled. The last portion of the schedule impression is the time at which all items on the order must be at the packer's bench. Only *one* customer's order receives this schedule and all items on that customer's order receives this *same* impression.

After the order is scheduled, the tickets are sorted according to the floor and department in which the merchandise is stocked. Following this, the item is sales listed—from this we get the total amount of sales for each day's business—and the entry tickets are dispatched by pneumatic tube to the various floors.

The handling on all floors is essentially the same—the tickets are priced, signed out to order fillers, wrapped and released to the spiral chute. The pricing is merely a check of the price entered by the customer against the catalog price to insure that the customer receives the lowest effective price for an item. Suppose a customer orders from the general catalog and the item is also listed at a lower price in a sale catalog. The pricing operation insures giving the customer the benefit of this lower price.

Each order filler is responsible for a certain number of items. She sorts the tickets into a numerical sequence and then picks the merchandise according to the information on the entry ticket. She attaches the entry ticket, with the schedule impression visible, to the merchandise.

Finally, the merchandise is released and conveyed to the spiral chute according to a pre-determined schedule which insures that the merchandise will reach the packer at the time shown on the schedule impression. At the bottom of the spiral chute, a series of conveyors transport the merchandise to what we call our primary sort. Here these girls, sorting by the first digit of the schedule impression, dispose the merchandise to a secondary belt which terminates at the section sorting station. The purpose of primary sort is to make it possible for the section sorter to handle only the orders for the ten packers which are in the section. It is a case of dividing and subdividing as a necessity for effective operation.

The section sorter, sorting by the first *two* digits of the schedule impression, disposes to one of two hoppers for each packing bench. She sorts to one hopper while the packer is working on the merchandise in the other hopper, and vice versa during the next schedule.

The packer goes through two major steps—receiving and packing. She first sorts the merchandise into the numbered bins, so that all items for one customer are in the same bin. After all merchandise is sorted, she packs the order carefully so the customer will receive the package in good condition and to insure that when the package is opened, the customer will find the merchandise neatly arranged. In tying the package, she uses a special knot, called the Sears knot, which was developed specifically for this purpose.

The order is disposed to a conveyor which leads eventually to the weigher who applies the correct amount of postage and disposes to the billing slide. Notice that there is an even distribution of work to all billers made possible by the automatic distributer which runs from one end of the billing slide to the other and back.

Billing is another important activity. It is here that the correct amount of the complete order is finally calculated. The amounts on all entry tickets are totaled, tax and shipping charges added, and this total is checked against the cash registered on the customer's original order form in the third operation we saw. Vouchers, in the case of refunds, and UOUs's, in the case of shortages, are attached to the bills. The paperwork is inserted in the package which is then conveyed to a branch office of the U. S. Post Office located in our building.

We have seen one example—it isn't quite as simple as the example shows, for there are many variations. There are Time Payment Orders, C.O.D. Orders, orders with samples enclosed, orders for merchandise which is sent to the customer direct from the factory, orders for merchandise too large to handle in the way we have shown, orders from retail store catalog sales desks, orders from Mail Order Catalog Sales Offices scattered in small towns all over the country, and there are irregularities in every type of order. The final result is that each person in the plant must be on his toes all the time if we are to get the right merchandise at the correct price to the customer. The fact that we are able to do so in all but a very few cases is a tribute to the people who are a part of the Sears organization.

INDUSTRIAL ENGINEERING AT SEARS

I think it must be fairly obvious to you now that effective retailing does require the services of the Industrial Engineering profession. Wage incentive systems requiring establishing fair production standards, effective processing requires special equipment and effective methods, and the tremendous quantity of merchandise handled requires the selection of the proper materials handling equipment. Methods Division activities include these as primary responsibilities.

We approach these problems in one of three ways: (1) The systems approach. (2) By applying the principles of Work Simplification. (3) The single aspect approach. All of these approaches follow the same basic, systematic, problem-solving steps.

In the first case, we may be asked to study all facets of the procedures or handlings in a particular department or group of departments. We study the basic procedural steps, the paperwork, the equipment and its arrangement, the people—everything which has a bearing on the problem. The end result will be better service to our customers (this is paramount in our minds) and more effective operations.

More and more we are making use of Work Simplification as an approach to solving problems. Here we call upon the know-how of a committee of people who are actually engaged in supervising or performing the work. We have conducted training classes for our key people to familiarize them with the fundamentals of methods work. These people are asked to study the problem on their own and to make suggestions as to how a particular operation can be improved. Then, when the entire group meets, the ideas these people propose are added to those of the Methods Division representatives and the final solution to the problem is developed. We have benefited in two ways from this approach: First, we have obtained some excellent ideas in brain-storming sessions which have led to large savings to the company, and second, and even more important, people who have a hand in making improvements more readily accept changes than they would if an outsider had suggested the change.

The single aspect approach is used when we are asked to design a particular piece of equipment or are assigned some similar miscellaneous problem. In this case we call upon our knowledge of the principles of Industrial Engineering to arrive at a solution with a minimum of time expended.

I have talked only of a general approach. I would like to call now upon someone else, one of your own, to discuss the specific techniques used in our work at Sears.

PART II

(Introduction of Miss Katherine E. Foster to discuss Industrial Engineering as practiced at Sears, Roebuck and Co.)

PART I (Concluded)

In addition to the tools which Miss Foster has told you about, we are also required to utilize other Industrial Engineering techniques. We mentioned materials handling earlier—we are responsible not only for the selection of conveying equipment, but for the selection of the heavier equipment used at our service warehouse as well—fork lift trucks, tractors for tractor-trailer trains, and stacking and other pallet handling equipment. Plant layout is involved in the design of additions to the buildings, as well as in the more effective use of existing space. Production planning and control is well established and depends now upon the physical facilities and available manpower, and most of all upon the needs of our final bosses, our customers.

The necessity for training people is always with us, but it is a problem of gigantic proportions to Sears because of the seasonal nature of the business. Each fall we employ and train more than 1000 new people to handle our Christmas business. The Training Supervisor, Mrs. Wray, is an important member of the Methods Division. So you see we are fortunate in having the services of more than one competent young lady in our department.

Electronic data processing is becoming more important to us, and with the advent of mechanized procedures, our people in the Methods Division are becoming more versatile and of more value to the company in developing mechanized systems. Methods and Auditing Departments share the responsibility for this phase of company progress.

In considering the activities of the Methods Division at Sears, it is interesting to realize how closely our objectives coincide to the principles voiced by Frederick W. Taylor:

1. Management as a science—not as a rule of thumb.
2. Harmony—not discord—between management and managed.
3. Cooperation—not individualism.
4. Maximum output—not restricted output.
5. The development of each man to his greatest potential.

It is interesting, too, to see how Industrial Engineering is a necessary part of a variety of industries—the basic industries, manufacturing industries, and as we have endeavored to convey to you today, a necessity for effective retailing.

INDUSTRIAL ENGINEERING — A NECESSITY FOR EFFECTIVE RETAILING (PART II)

by MISS KATHERINE E. FOSTER

Management Technician—Sears, Roebuck and Co.

INDUSTRIAL ENGINEERING TECHNIQUES

MY remarks today will be concerned with a discussion of some of the Industrial Engineering techniques which we use most frequently. We will talk about time study, statistical analysis, methods study, layout and job evaluation as problem solving tools and will relate a case study to tell you how they have been used on an actual project at Sears.

Probably the most familiar tool of the Industrial Engineer is time study. If you saw the musical show *The Pajama Game,* perhaps you remember Hines, the time study man in the pajama factory, who carefully studied his stop watch while he urged the factory girls to hurry—hurry.

This, I suspect, is the conception that many people have of time study. The time study man—or woman—*does* carefully read his watch, and he *does* observe employees at their work. That much of the picture of the time study man is correct.

Work measurement is essential in industry, if we are to keep ourselves informed about the costs of the various phases of our operation. Stop watch time study is the best known method of measuring the amount of time required to perform an operation.

This is the stop watch we use. It gets its name, split-hand watch, from the fact that one of the two large hands may be stopped to permit reading and recording of time. At the same time the other hand continues to measure the time required for the following element. The markings around the outer edge of the face designate hundredths of a minute. The small dial records whole minutes.

Industrial Engineers try to simplify the work methods of others and to increase the effectiveness of effort spent by others in doing work, but we have also tried to simplify and make our own efforts more productive. Standard data is one example of how this concept has been applied to time study. Another is Predetermined Time Systems such as MTM and BMT.

Both of these systems describe minute elements of work and make use of previously determined times. Generally, the difference in the two lies in the degree of fineness in elemental breakdown.

Standard data systems use complete work elements, so this system is nothing more nor less than the re-use of previously established times. On the other hand, Predetermined Time Systems reduce the elements to the basic motions required to perform work. For example, an element description under the standard data system might read, "Place cap on fountain pen." Under BMT this operation would be broken down into a series of reaches and moves.

The methods of deriving times under the two systems are somewhat different also. Standard data times are usually developed from stop watch studies and are used within the company which developed them. Basic Motion Times and those for other such systems are developed under controlled conditions which may make use of other work measurement devices.

In using these systems the engineer must be sure that the time he selects fits the operation being studied.

Time studies serve many purposes in industry, but none of them is the hurry—hurry concept presented by the gentleman we mentioned earlier.

Some examples of its uses are in the setting of production standards, in determining labor costs of operations, in connection with cost accounting systems, and as a planning tool.

At Sears some of our employees work in departments where wage incentive plans are used. By time study we determine how many orders or letters our employees should process in an hour, and they receive additional pay when their performance is above the standard. In no case do they receive less than their basic hourly rate.

Another use is in determining the labor costs of various operations. Once we know how long an operation takes, we merely apply the hourly rate for the job to determine its cost. Sometimes we are called upon to choose the most economical of two or more possible ways of performing a job. Determination of labor costs of the possible ways helps us to make such decisions.

Sears has some 50 odd merchandise departments such as the shoe department, hardware department, kitchenware department. Each year our accountants prepare a net profit statement for each of these departments so that we can tell which departments are profitable and which ones are encountering problems. This means that all of our income and all of our expense must be divided into

50 odd portions. Time studies help us to determine an equitable basis for dividing some of these expenses among the many departments.

Time studies are used also in standard cost accounting systems. Last year Sears installed its first standard cost system for a non-manufacturing operation. The Sears unit involved was our local fashion distribution center. Our time studies in this instance were for use in setting up budgets based on the volume of women's fashions that the center expected to handle. Actual expenses were then compared with the budgets so that problem areas could be highlighted for correction.

Time studies help us to plan the size of our work force in advance. When we know how long it takes to process one order and have estimated the total volume of orders that we expect to receive during a given period, then it is a simple matter for us to determine the number of people required.

Another tool of the Industrial Engineer is statistical analysis. Indirectly we have already talked about it, because statistical analysis deals with the mathematical side of engineering.

Fundamental statistical techniques are used in time study to select from a large number of variable readings the most representative time for the given element.

This slide shows a summary of stop watch readings for one work element. Time values are arranged in ascending order and opposite each value is shown the number of readings recorded for that value. The lowest and highest reading and the one which occurred most often can be determined at a glance.

Such data can also be converted into graphs, curves, or charts for pictorial presentation.

Similar analyses can be made using other kinds of numerical data such as sales, expenses, and orders.

More refined statistical techniques are used in connection with work sampling studies. Statistics tells us that a sample of adequate size will reflect true conditions. For instance, random observations of the operation of a machine permit us to establish the percent of down time of the machine without having to continuously observe its operation; thus releasing us for other more productive activities.

Methods study is another of the Industrial Engineer's tools. Methods study can help our employees turn out more orders by finding easier ways to perform necessary work.

Frequently, a process chart is prepared to show a picture of the operation. The chart is studied with the idea, first, of eliminating non-productive or unnecessary steps in the process. Remaining steps also are analyzed carefully to combine or change the sequence of operations, where this can provide a smoother flow of work. Finally, an effort is made to simplify the operation through the use of principles of motion economy—(1) Use the lowest possible motion classification—for example, use a finger movement rather than an arm movement. (2) Locate supplies and equipment as conveniently as possible to the work place. (3) Provide a particular place for everything that is to be used and have everything in its place to eliminate the necessity of searching. (4) Use jigs for holding so that the hands are free for productive work. (5) Use gravity for movement of work or supplies. Unlike mechanical equipment, it never breaks down.

The flow diagram is another technique of method analysis. It is simply a floor plan of the operation being studied with lines and arrows to show the path followed by work being processed. The flow diagram quickly shows back-tracking or excessive distances between operations and helps the engineer to develop a more convenient grouping of desks or other equipment.

And, of course, there are other methods study tools that can be used depending upon the scope of the study.

The discussion of Flow Diagrams brings us to another Industrial Engineering technique: Layout.

Plant layout is the development of improved departmental arrangements or location of equipment within a department by the use of scale drawings, templates or scale models. Changes can be made faster just by moving a scale model of a piece of equipment than by making a change on a drawing. Another advantage of scale models or templates is that they are more easily interpreted than blueprints by people who seldom have occasion to read blueprints.

In developing a layout we make use of our knowledge of materials flow, processing time, material handling methods and equipment, and recognized standards for spacing of equipment, lighting, heat and ventilation.

All of us know that some jobs are more difficult than others. Job evaluation is the technique used to recognize and to evaluate these differences to determine the relative values of a group of jobs.

The first step in job evaluation is the preparation of job descriptions. These descriptions tell in narrative form and in succinct language what is done on each job.

Next the jobs are rated or scored on various factors such as educational requirements, physical requirements, amount of initiative necessary, and other factors. Our ratings are based on a numerical point system so that the total score for each job can be determined after it has been rated on all factors. The scores of all jobs arranged from lowest to highest are the basis for deciding which jobs will carry the lowest and highest rates and the relative positions of those in between. This is the primary use of job evaluation. However, it has other uses. For instance, job evaluation is an aid to the selection of new employees since the qualifications of the person needed to fill a vacancy are indicated by the ratings on the various factors involved on a job. For the same reasons, job evaluations are a guide in transferring or promoting personnel from one job to another.

Job evaluation is not an exact measure, since judgment is used all along the way. But it is a systematic rather than a haphazard way of determining relative wage rates, and as such it contributes to better relations between employees and management.

SELECTION OF THE PROPER TECHNIQUES

We have talked about time study, statistical analysis, methods study, layout and job evaluation. How do we decide which to use? Sometimes the nature of the job will determine the correct tool; for example, in setting a production standard we will use time study. On other jobs it is not so easy to decide.

The question in this case is primarily one of economics—that is, what are the probabilities of producing monetary savings? The possibility of substantial savings justifies a considerable investment of engineering time.

Repetitiveness is one factor considered. A small saving on an operation grows into a significant amount if the operation is repeated hundreds of times in a day. For the same reason the duration of the operation must be considered. An operation which will last only a few months will not require the careful study that a permanent operation does. Jobs that consist primarily of time controlled by the employee himself usually offer more possibility for savings than jobs which are machine controlled.

And, of course, the higher the rate paid for an activity the more worthwhile the time saving.

USES OF INDUSTRIAL ENGINEERING TECHNIQUES

We have discussed several techniques which are used by all of us in the Methods Division and how we decide which ones to use. To sum up, then, let's see what was done on an actual project at Sears.

As you may know Sears Catalog Sales Offices are located in many of our smaller cities. These offices have displays of some catalog merchandise, swatch books showing samples of fabrics, and samples of other goods we sell. Customers can come to these offices or to the Catalog Order Desks in our retail stores, study the samples and the catalog, and then have our clerks write their orders for them. Formerly, the orders were mailed to the nearest Sears Mail Order Plant to be filled.

Our management decided to improve service to our customers by connecting these selling units directly with the mail order plant by teletype. Formerly our selling units held all orders until the end of the day. With teletype, after accumulating several orders, a clerk sits down at a teletype machine and types the information needed to fill and ship the order. The order is received immediately in the mail order plant typed in a form ready for subsequent processing.

This change means that some clerical departments, which formerly handled the mailed-in orders, now are by-passed by the teletype orders. Consequently, these departments now require fewer employees and less floor space than formerly. On the other hand, we acquired a new department—the one where the teletype orders are received.

The objectives of our study were:

1. To provide new layouts for the departments by-passed by the teletype orders.
2. To consolidate the spaces thus saved into an area located most advantageously for the installation of our teletype machines with respect to order flow, access to machine service facilities and nearness to other teletype equipment in our message center.
3. To provide balanced movement of orders from machines through various operations within the teletype order department.

The scope of this project called for a systems approach which Mr. Green described to you. From the standpoint of economics, the project qualified for an intensive study.

Actually, all five of the techniques we have mentioned were used.

First of all, methods analysis was used in planning the sequence and the location of the several operations which occur within the teletype department. The slide shows a flow process chart of the teletype order department.

Teletype service was provided first for a small group of selling units. Time studies made in this pilot installation were helpful in planning the number of work places to be provided for the performance of each operation. The slide shows a time study being made on the operation of tearing the continuous sheet of teletype paper into individual orders.

Statistical analysis was necessary at almost every step in the study—for example, in summarizing time study data, in determining the number of work places required according to anticipated volume of orders, and in deciding upon teletype machine groupings for balanced flow of incoming orders. The chart on the screen is a frequency distribution of time values for the work element we saw being studied in the previous slide.

Then new layouts were developed for all the departments affected. We used cut outs representing desks, file cabinets and other equipment in working with the division head of each department to develop a good layout. The layout on the screen is the one which resulted.

And finally, job evaluation was necessary, too, because new kinds of jobs were created. Job descriptions were written so that the rates for these jobs were created. Job descriptions were written so that the rates for these jobs could be properly related to the rates on our other jobs.

Work simplification techniques were employed, also, in that we worked closely with the employees affected in all of the planning for the teletype order department.

Many of the projects assigned to our department fall into the miscellaneous category that Mr. Green mentioned. For example, when new business machines are to be purchased, we sometimes are asked to compare two or more available makes or models. A study of this kind involves methods analysis, time study and statistical analysis. Cost studies are another kind of miscellaneous project. Sometimes a choice must be made between two or more possible methods of performing an operation, or sometimes we need to know how much a particular operation costs. A study of this type also requires methods analysis, time study and statistical analysis. Setting production standards for use in a wage incentive system involves use of the same three techniques also. Finally, we may be asked to design business forms to serve special purposes. This also requires methods analysis and sometimes statistical analysis as well.

We could talk about other techniques and other kind of projects; for, believe me, the work we are called upon to perform runs the gamut from the ridiculously simple to the impossible difficult. However, I hope that this discussion has given you an idea of what we do; and, more specifically, of what I, as a member of the Industrial Engineering profession, am called upon to do.

(Mr. Green now concludes Part I)

section 31

Chief Industrial Engineers' Symposium

Session I

Industry's Need vs. Education's Supply

MODERATOR
Daniel E. Mahaffey

PANELISTS
Dr. Clifton A. Anderson
Richard F. Bergmann
Col. Frank F. Groseclose
Robert J. Rohr

ALTHOUGH our colleges and universities are turning out graduates at an unprecedented rate, the demand for good engineering and scientific talent still far exceeds the supply. Is the product our colleges are producing today the one industry will need tomorrow, or are the schools turning out a mediocre product simply because it satisfies a heavy demand? There are those who feel that our colleges are not living up to their responsibility not only to keep pace with industry but to stay ahead of it. Yet, business and industry, too, have a responsibility to work with the educators or they will find themselves increasingly in the position, in the years to come, of having to accept an obsolete product from the schools which they must up-date prior to use.

In this age of rapid advances in all fields, it behooves industry to keep the schools informed of the areas in which they are working, in which particular fields their new engineers are weakest, and which courses are most important from their view point. Of course, no one, least of all industry itself, wants our industrial personnel men running our institutions of higher learning, but by the same logic neither do we want our colleges, by emphasis on certain courses, dictating to business the directions it should take in its future progress. Only by cooperating in close liaison with the schools can industry expect to receive the type of graduate it needs in the future.

DANIEL E. MAHAFFEY

MODERATOR

Chief Industrial Engineer
Eastman Kodak Company
Processing Laboratory
Chamblee, Georgia

MR. MAHAFFEY is an Industrial Engineering graduate of the Georgia Institute of Technology. He is a member of Alpha Pi Mu and Tau Beta Pi. In his varied experience, Mr. Mahaffey has been in steel fabrication, the printing trades, warehousing and shipping, and film manufacturing and film processing. Since 1950 he has been with the Eastman Kodak Company, working in many of their plants in Rochester, Toronto, and Chicago. He is currently in charge of the Industrial Engineering Department in Kodak's Atlanta Processing Laboratory. Mr. Mahaffey is the author of several articles in the field. He is the First Vice-President of the Atlanta Chapter, A.I.I.E.

DR. CLIFTON A. ANDERSON

PANELIST

Head, Department of Industrial Engineering
North Carolina State College
Raleigh, North Carolina

MR. ANDERSON received his B.S. from the University of South Dakota, his M.S. from Pennsylvania State University, and his Ph.D. in Industrial Engineering from Ohio State.

Formerly Professor of Industrial Engineering at Pennsylvania State University, he is now Professor and Head of the Department of Industrial Engineering at N.C. State College.

Mr. Anderson is a Registered Professional Engineer in Pennsylvania and past National President of Alpha Pi Mu, the Industrial Engineering honorary fraternity.

RICHARD F. BERGMANN

PANELIST

Vice-President, Engineering
Link Belt Company
Chicago, Illinois

MR. BERGMANN is Vice President and Chief Engineer, and a member of the Board of Directors of the Link-Belt Company, a major manufacturer of power transmission and materials handling equipment with headquarters in Chicago. A graduate of Rose Polytechnic Institute, he came with Link-Belt's Caldwell Plant in 1924.

Mr. Bergmann was promoted to Assistant Chief Engineer at the Executive Offices in 1933 and promoted to his present position in 1944. He is a life member of the Board of Managers of Rose Polytechnic Institute.

In directing and building the entire Link-Belt engineering function, he is extremely interested in the proper selection and development of young engineers. He has spoken before many groups on the subject of this forum.

COL. FRANK F. GROSECLOSE

PANELIST

Director, School of Industrial Engineering
Georgia Institute of Technology
Atlanta, Georgia

MR. GROSECLOSE received his B.S. in Mechanical Engineering in 1928. Subsequently he joined V.P.I. as an instructor and in 1932 received his M.S. in Mechanical Engineering. In 1936 he joined the University of North Carolina as an Associate Professor of Mechanical Engineering, a position he held until 1939 when he became Associate Professor of Industrial Engineering. In 1945 he came to Georgia Tech where he organized and became Director of the School of Industrial Engineering, the position he holds today.

He is a Registered Professional Engineer in both Georgia and North Carolina and the author of numerous articles on mechanical and I.E. subjects for technical publications. He is co-author (with R. T. Staton) of the text *Industrial Reports*.

ROBERT J. ROHR

PANELIST

Assistant Director, Industrial Engineering Division
Eastman Kodak Company
Rochester, New York

AFTER SEVERAL years' experience with General Motors which encompassed product design, plant layout, methods, and general Industrial Engineering, Mr. Rohr joined Eastman Kodak in 1938 and in 1940 became Administrative Supervisor of the Accounting Department. In 1946 he joined the Industrial Engineering Division for which he organized field engineering and was later placed in charge of Industrial Engineering Methods for the Kodak Park Works. For the past ten years he has held the position of Assistant Director of the Industrial Engineering Division at Kodak Park. The Division employs over 300 people who provide Industrial Engineering services for Kodak Park, processing laboratories, branches, and affiliated companies in the United States and foreign countries.

Mr. Rohr is the author of "Operations Research —A New Cost Cutting Tool" published in the National Industrial Conference Board Business Record, volume X, No. 7, July 1953. He is affiliated with several professional and civic organizations which include the National Association of Cost Accountants, the Operations Research Society of America, the AIIE, and the Rochester Chamber of Commerce.

Chief Industrial Engineers' Symposium

Session II

The Present Scope of the Industrial Engineering Department

MODERATOR
Grover N. Meinert

PANELISTS
John M. Murray
Omar K. Vandament
Mark L. Wilton

THE American Institute of Industrial Engineers has an official definition that makes the outline of their work seem relatively simple. However, in actual practice there is a wide diversity in responsibility among Industrial Engineering departments. The organizational set-up of the various departments, both intra- and inter-departmentally, range from the very simple to the extremely complex. The basic duties of an I.E. department may range from simple time-studies for day-work applications to divisional organizations encompassing such fields as quality control, operations research, and data processing. Essentially, the goal of all I.E. departments is the same; how they accomplish this goal in plants of 300, 3000 or 15,000 employees may vary quite widely.

There are plants where the Industrial Engineering department reports directly to the works manager, others where they work through the company comptroller, and still others where the Industrial Engineer functions in a line capacity rather than staff. Each has its own advantages and disadvantages. However, to operate to its greatest advantage in its function to "specify, predict, and evaluate", the Industrial Engineering department needs an air of unbiased freedom in which to work.

GROVER N. MEINERT

MODERATOR

Chief Industrial Engineer
Atlantic Steel Company
Atlanta, Georgia

After receiving his Bachelor of Industrial Engineering degree from Georgia Tech in 1947, Mr. Meinert joined the Tennessee Coal, Iron, and Railroad Company. After a short period for them, he returned to Atlanta as an Industrial Engineer with the Atlantic Steel Company.

In 1952, he received the degree of Master of Science in Industrial Engineering from Ga. Tech.

In 1956, he was named Manager of Systems and Procedures for Atlantic Steel Company.

In 1958, he was named Chief Industrial Engineer of Atlantic Steel Company, in which capacity he now serves.

He was one of the founders of the Atlanta Chapter of the AIIE and has served in the capacity of secretary.

He has been the president of the Atlanta Chapter of the American Materials Handling Society. He is also a member at large of the Systems and Procedures Association of America.

JOHN M. MURRAY

PANELIST

Chief Industrial Engineer
Vanity Fair Mills
Monroeville, Alabama

PRIOR TO RECEIVING his B.S. in Forestry from the University of Georgia, Mr. Murray studied chemical Engineering at Georgia Tech. Later, he studied accounting (USAFI) and Industrial Engineering (under J. D. Woods and Gorton, Ltd.).

His industrial experience includes forest surveying, logging, and light construction; woven textiles—Chicopee Manufacturing Co. (5 years); Industrial Engineering Consulting — Henderson, Lindsay and Michaels; and hosiery, needles trade, lingerie—Tricot Knitting (5 years).

Currently, Mr. Murray is the Chief Industrial Engineer of Vanity Fair Mills, Inc.

OMAR K. VANDAMENT

PANELIST

Chief Industrial Engineer
Conway Division
Virco Manufacturing Company
Conway, Arkansas

MR. VANDAMENT served 3½ years in the U.S. Army Air Force during World War II. In 1952 he received his Master of Science degree from the University of Arkansas. From 1952 to 1955 he was employed as an Industrial Engineer with Redmond Motors Co.—a manufacturer of fractional horsepower electric motors. From 1955 to the present he has been employed as an Industrial Engineer in the manufacture of school furniture by the Virco Manufacturing Corporation.

MARK L. WILTON

PANELIST

Chief Industrial Engineer
Lockheed Aircraft Corporation
Georgia Division
Marietta, Georgia

MR. WILTON is a graduate of Stanford University with a B.A. in Economics and a Master's degree in Business Administration.

His industrial experience prior to joining Lockheed included work for the Stanford Research Institute as an Industrial Engineer, for the Arabian Oil Company as an organization specialist, and for Mission Metalcrafters as General Manager.

Since joining Lockheed Mr. Wilton has had such positions as Systems Analyst, Executive Assistant to the Works Manager, Audit and Analysis Department Manager, and Industrial Engineering Department Manager. At the present time he is the Chief Industrial Engineer of Lockheed's Georgia Division. In this position he is responsible not only for the Industrial Engineering Department, but also for the Time Standards and Direct Hours Control Departments.

section 33

Chief Industrial Engineers' Symposium

Session III

The Role of Electronic Equipment in the Industrial Engineering Department

MODERATOR
Dr. A. Richard Marks

PANELISTS
Earl G. Fossum
Cleggett A. Jones
Alan O. Mann
Cecil P. Webb

ONE of the more recent tools in the hands of the Industrial Engineer, and probably the one destined to have the most far-reaching effects is electronic data processing (EDP) equipment. The average Industrial Engineer has hardly had time to digest the concepts of basic data processing and the new horizons it opens up, much less keep up with the rapid advances that are being made in the field. Such terms as Ramac, Transac, Univac, etc. have been added to our vocabulary, and now we find out that the equipment is getting so complex that it requires computers to program computers. And yet, EDP is a powerful tool that enables the engineer and scientist to accomplish jobs that at one time seemed hopeless in their man-hour requirements. It may be a long time before the average Industrial Engineer will completely understand, program, and run a data processing installation, but it is essential to his future that he inform himself of its capabilities and the ever-increasing potential that it has for performing impossible tasks.

Although computer installations may be at present too expensive for the small plant, newer developments in the field are bringing closer the day when the advantages of the electronic computer will be available economically to even the smallest business. Transistomized computers, by reducing air conditioning and space requirements and thus installation costs, and independent EDP services on a fee basis now available in many cities, are but two examples of the progress being made in this direction.

DR. A. RICHARD MARKS

MODERATOR

Supervisor, Data System & Operations Research
The Martin Co.
Denver, Colorado

DR. MARKS is currently Supervisor of Business Data Systems and Operations Research activities at the Denver Division of the Martin Company. These activities are carried out on a company-wide basis and range from the simulation of job shop type manufacturing operations to the mechanization of bills of materials on engineering drawings.

Dr. Marks graduated as a Mechanical Engineer from Manchester University (England) in 1948. He performed graduate work at California Institute of Technology, obtaining his Master's degree in Electrical Engineering in 1949, and in 1954 was awarded a Ph.D. in the field of Industrial Engineering from the University of California at Berkeley.

Dr. Marks has carried out research in job design, biomechanics, cargo handling, and agricultural harvesting. He has published several articles in industry journals on the result of his studies and has presented papers to such groups as the American Psychological Association, the International Association of Applied Psychology, and the Operations Research Society of America.

In 1956 Dr. Marks joined the faculty of the School of Engineering, Yale University, as Assistant Professor of Industrial Administration. He taught in the field of management, manufacturing analysis, Industrial Engineering, and electronic data processing for business and industry.

Dr. Marks has consulted with several firms in the Industrial Engineering and Operations Research field.

EARL G. FOSSUM

PANELIST

Director, Systems Study and Design
Product Planning Division
Remington Rand Univac Division
Sperry Rand Corporation
Philadelphia, Pennsylvania

EARL G. FOSSUM, a 1938 graduate of Whitman College, Walla Walla, Washington, has had 20 years of experience in business data processing procedures and applications. Prior to entering the Navy in early 1944, he worked as a senior statistician and procedures analyst for the State of Washington. After two years as an electronics officer, he transferred to the Navy Supply Corps, and remained on active duty for over eleven years, with duties centering on the development of military inventory control methods and procedures. During the three years preceding his resignation as a lieutenant-commander, he established and headed the Navy Supply System's EDPM applications program. Since August 1955, he has been associated with Remington Rand Univac Division of Sperry Rand Corporation, and is presently Director of Systems Study and Design, Product Planning Division, in which capacity he is responsible for the development of detailed functional specifications of electronic data processors for both business and scientific use. Mr. Fossum is a member of Phi Beta Kappa, Society for Industrial and Applied Mathematics, American Statistical Association and the Association for Computing Machinery.

CLEGGETT A. JONES

PANELIST

Atlanta District Manager
Electrodata Division
Burroughs Corporation
Atlanta, Georgia

MR. JONES, a graduate of George Washington University, has been active in the data processing field for nine years. During this time he has been closely associated with the installation of some twenty-five electronic data processing machines. At present he is the Atlanta District Manager for the Electrodata Division of the Burroughs Corporation.

ALAN O. MANN

PANELIST

Commercial Coordinator, Computers
Philco Corporation
Philadelphia, Pennsylvania

MR. MANN is presently employed as a Commercial Coordinator in the field of Computers and Automation by the Philco Corporation.

Prior positions that Mr. Mann has held include Senior Principal, Alan O. Mann Associates; Management Consultant to the Philco Corporation; and Assistant to the Secretary of Defense for Manpower, Air Material Command, USAF.

Other positions include Commercial Coordinator, SKF Industries; President, Crusader Press, Inc.; Operating Vice-President, Peter F. Mallon, Inc.; Assistant to the President, Bigelow-Sanford Carpet Co.; and many others.

Mr. Mann is a graduate of Hobart College and has instructed at both Temple University and New York University.

He has been Planning Counsel for the American Management Association and Business Manager for the Institute of Management Sciences.

Mr. Mann is listed in Who's Who in Commerce and Industry.

CECIL P. WEBB

PANELIST

Resident Representative
To Lockheed Aircraft Corp., Ga. Div.
International Business Machines
New York, New York

MR. WEBB received his B.S. in Business Administration from Mississippi Southern College.

In 1954 he joined IBM's Atlanta office and in 1955 was assigned to assist the Lockheed Aircraft Corporation's Georgia Division (located in Marietta, Ga.) in the installation of two large scale computers. Upon completion of this installation Mr. Webb continued to be IBM's resident representative to Lockheed's Georgia Division.

Mr. Webb has had over four years of applying small, medium, and large scale computers to problems in the manufacturing area.

EXHIBITORS

AT THE

*10th Annual National Convention and Conference**

IN ALPHABETICAL SEQUENCE

ACME STEEL COMPANY
ADDRESSOGRAPH-MULTIGRAPH COMPANY
A.I.I.E. ATLANTA CHAPTER HOST BOOTH
AIRCO SUPPLY COMPANY, INC.
ALDEN SYSTEMS COMPANY, ALDEN RESEARCH CENTER
AMERICAN MONORAIL COMPANY
THE BELLOWS COMPANY
DELTA AIR LINES, INCORPORATED
GEORGIA CHAMBER OF COMMERCE
GEORGIA INSTITUTE OF TECHNOLOGY
HALOID XEROX COMPANY
HAMILTON MANAGEMENT CORPORATION
IMPERIAL METALLIC LUBRICANTS, INCORPORATED
J. O. KING, INCORPORATED
LOCKHEED AIRCRAFT CORPORATION, GEORGIA DIVISION
MEYLAN STOPWATCH COMPANY
THE MIMEOGRAPH COMPANY, A. B. DICK DUPLICATING PRODUCTS
MTM ASSOCIATION FOR STANDARDS AND RESEARCH
NATIONAL A.I.I.E. HEADQUARTERS
THE RAPIDS-STANDARD COMPANY, INC.
STANDARD CONVEYOR COMPANY
THERMOFAX-3M COMPANY
THOMAS A. EDISON INDUSTRIES, VOICEWRITER DIVISION
TIER-RACK CORPORATION
UNITED ENGINEERING TRUSTEES
UNIVERSITY OF FLORIDA
THE WORK-FACTOR COMPANY, INC.

***As of April 15, 1959.**

Senior Chapters

1. Columbus, Ohio
2. Dayton, Ohio
3. Pittsburgh, Pennsylvania
4. Jamshedpur, India
5. Metropolitan New York
6. Atlanta, Georgia
7. Cleveland, Ohio
8. Cincinnati, Ohio
9. Birmingham, Alabama
10. Dallas-Ft. Worth, Texas
11. East Tennessee
12. San Francisco-Oakland, Calif.
13. Syracuse, New York
14. Washington, D. C.
15. Tulsa, Oklahoma
16. St. Louis, Missouri
17. Tri-Cities, Tennessee
18. Louisville, Kentucky
19. Stark County, Ohio
20. Seattle, Washington
21. Winston-Salem, North Carolina
22. Houston, Texas
23. Los Angeles, California
24. Youngstown, Ohio
25. Chicago, Illinois
26. Savannah, Georgia
27. Jacksonville, Florida
28. Memphis, Tennessee
29. San Diego, California
30. Boston, Massachusetts
31. Philadelphia, Pennsylvania
32. Rocky Mountain, Colorado
33. Pensacola, Florida
34. Fort Wayne, Indiana
35. Central Indiana
36. Toledo, Ohio
37. Peninsula, California
38. Twin City, Minn. & Wis.
39. San Antonio, Texas
40. Miami, Florida
41. Baton Rouge, Louisiana
42. Baltimore, Maryland
43. Sacramento, California
44. Rochester, New York
45. Milwaukee, Wisconsin
46. Mississippi Valley, Ia. & Ill.
47. Detroit, Michigan
48. Southern Tier, New York
49. Niagara Frontier, New York
50. Great Salt Lake, Utah
51. Erie, Pennsylvania
52. Akron, Ohio
53. Calumet, Indiana
54. Chattanooga, Tennessee
55. Macon, Georgia
56. Wichita, Kansas
57. Oklahoma City, Oklahoma
58. Charleston-Huntington, W. Va.
59. Albuquerque Area, N. M.
60. East Texas
61. Metropolitan New Jersey
62. Merrimack Valley, N. H. & Mass.
63. Tri-State, New Hampshire
64. Middle Tennessee
65. Indianapolis, Indiana
66. Eastern North Carolina
67. Portland, Oregon
68. Worcester, Massachusetts
69. North Alabama
70. Central Arizona
71. Lancaster Area, Pennsylvania
72. York, Pennsylvania
73. Nashville, Tennessee
74. New Orleans, Louisiana
75. Central Connecticut
76. Mid-Hudson, New York
77. Lehigh Valley, Pennsylvania
78. San Gabriel Valley, California
79. Mobile, Alabama
80. Central Illinois
81. Western Virginia
82. Southwestern Connecticut
83. Western North Carolina
84. Central Arkansas
85. Mohawk Valley, New York
86. Long Island, New York
87. Southern Ontario, Canada
88. Evansville, Indiana
89. Susquehanna Valley, Penn.
90. Omaha, Nebraska
91. Florida West Coast
92. Kansas City
93. Northwest Georgia
94. Springfield, Massachusetts

Student Chapters

University of Alabama
University of Arkansas
Bradley University
University of California
University of Southern California
Case Institute of Technology
Columbia University
University of Florida
Georgia Tech
University of Houston
Illinois Institute of Technology
Iowa State College
State University of Iowa
Johns Hopkins University
Lafayette College
Lamar State College of Technology, Texas
Lehigh University
University of Missouri
Montana State College
New York University (Day Division)
New York University (Evening Division)
North Carolina State College
Northeastern
Northwestern
Ohio State University
Oklahoma State University
Oregon State College
Pennsylvania State University
University of Pittsburgh
Purdue University
Rutgers University
Stanford University
Syracuse University
University of Tennessee
A & M of Texas
Texas Tech
University of Utah
Virginia Polytechnic Institute
Washington University
Wayne State University
West Virginia University